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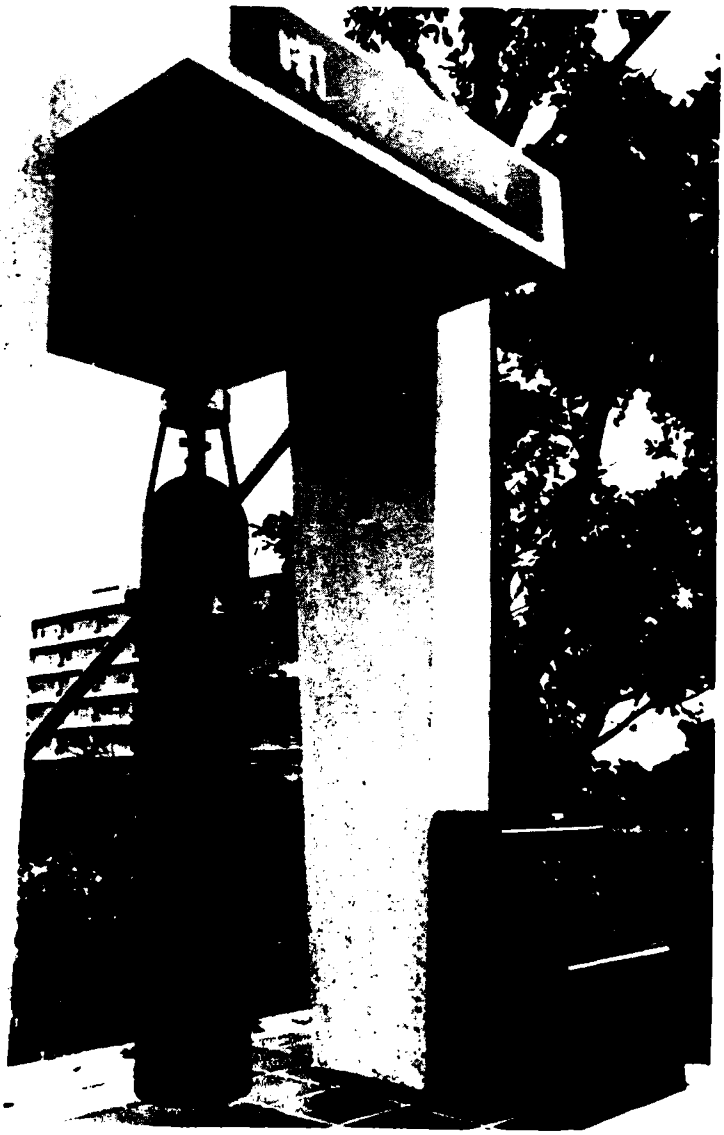

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This is a quarterly publication presenting articles covering recent developments in Far Eastern (particularly Japanese) scientific research. It is hoped that these reports (which do not constitute part of the scientific literature) will prove to be of value to scientists by providing items of interest well in advance of the usual scientific publications. The articles are written primarily by members of the staff of ONR Far East, the Air Force Office of Scientific Research, and the Army Research Office, with certain reports also being contributed by visiting stateside scientists. Occasionally, a regional scientist will be invited to submit an article covering his own work, considered to be of special interest. This publication is approved for official dissemination of technical and scientific information of interest to the Defense research community and the scientific community at large. It is available free of charge to approved members of the DOD scientific community. Send written request describing DOD affiliation to: Director, Office of Naval Research, Liaison Office Far East, APO San Francisco 96503-0007.

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CONTENTS

Cover: When the University of the Ryukyus was founded in 1950 by the U.S. occupation authorities, its first "bell" was a U.S. Army high pressure gas tank. Proud of its unique origin, the university has the bell handsomely mounted outside the President's Building. The inscription reads "Kaigaku No Kane" (original school bell), and the engraved stone at the base tells the story. See article on page 47.

SUPERCONDUCTING MOTORS, GENERATORS, AND POWER SYSTEMS

Earl Callen, Fred Pettit, Louis Aprigliano, and Om Arora

Niobium alloy wire at liquid helium temperature remains superconducting in magnetic fields as high as 30 T, for certain alloys. This property is the basis of a large number of applications depending upon the generation of large magnetic fields by solenoids and coils: medical nuclear magnetic resonance, ship motors and generators, magnetohydrodynamic ship propulsion, dc synchronous motors and generators for electrical power systems, superconducting magnetic energy storage for power handling and network stabilization, and transformers. To minimize ac loss in applications with variable current, ultrafine, multifilament, tightly kinked and twisted wire is used. Japan is a major world supplier of superconducting wire. Japanese research and development efforts in applications of conventional superconductors are beginning to yield their bounty.

INTRODUCTION

In the glamorous glow of high T_c it is easy to overlook the growing technological impact of conventional superconductivity. In power handling and high current applications, as distinguished from electronics, much of this impact derives from the ability of the niobium-based alloys--NbTi, Nb_3Sn, Nb_3Al, and other related materials (V_3Ga)--to carry large electrical currents and withstand very large magnetic fields without losing their superconducting properties. The gestation period of "industrial" superconductivity was more than half a century--going back to 1911 when Kamerlingh Onnes discovered the resistance of mercury to go to a value so low that he could not distinguish it from zero. And characteristically, Japanese manufacturers--Furukawa Electric, Hitachi Cable, Showa Electric, Fujikura, and Sumitomo Electric--have been laboring for more than 25 years to perfect superconducting magnet wire. Though their dominance is not uncontested, they are major world suppliers. The Ministry for International Trade and Industry (MITI) under its "Moonlight Project" and the Science and Technology Agency (STA) under its "Multicore Project," through the great national research laboratories [especially STA's National Research Institute for Metals (NRIM) and MITI's Electrotechnical Laboratories (ETL)] and through the industrial grouping [the Engineering Research Association for Superconductive Generation Equipment and Materials (Super GM)], have stimulated, coordinated, and supported long-sustained and well-funded programs.

Superconductors will be used in power transmission cables and in coaxial communication cables. But among the most important applications will certainly be those utilizing magnets. The key technology here is the superconducting solenoid and coil. Operating in the persistent current mode (zero resistance in the reentrant superconducting winding), the current circulates through the coil unattached to its power source, generating and maintaining the large magnetic field with no loss. The mainstay of the industry for now is magnets for medical nuclear magnetic resonance [renamed magnetic resonance imaging (MRI) by the medical practitioners]. But niobium-based wire and cable will be used in the superconducting supercollider, maglev trains, electric generators, particle detectors (Topaz, in the Japanese KEK Tristan project), transformers, magnetic confinement fusion devices, superconducting motors, magnetohydrodynamic ship propulsion, superconducting energy storage systems, and materials processing. In electrical power generation and handling, superconductive devices have the advantage of high efficiency (low loss), small equipment size and weight, large power handling capability, and flexibility of equipment design.

Niobium-based alloys have superconducting transition temperatures between 10 and 17 K. But since the transition temperature is reduced in a magnetic field (including the field generated by the current itself), it is necessary in application to keep the wire at liquid helium temperature (4 K). Liquid He has an extremely small latent heat and specific heat. It is a poor cooling agent; the efficiency of cooling the superconductor to liquid He temperature is less than 0.2 percent. Therefore, thermal insulation is essential. In those electrical power applications in which thermal isolation is expensive, superconductivity will be most competitive in large systems. In addition, there are ac losses in superconductors. So the push is toward large systems, dc applications, and the development of materials and designs with reduced ac loss.

SUPERCONDUCTING SHIP MOTORS AND GENERATORS

In principle, electric motors and generators are inverse devices. Two machine designs are possible, namely dc acyclic machines and ac synchronous machines. Because of their capability for full torque at all speeds and lower refrigeration requirements, dc acyclic machines are more suited to ship propulsion. A superconducting motor can be considered to consist of a superconducting winding to generate the magnetic flux, a cryostat, the current collector, the armature, and an iron magnetic shield yoke. In the homopolar design to be discussed, the solenoid is the stator and the armature is the rotor, on the outside of the superconducting coil. The coil generates a radial magnetic field, which returns through the relatively high permeability magnetic shield yoke that surrounds the coils. As in any electric motor a rotational force, the Lorentz force, is developed on the cylindrical armature by the magnetic field acting on the current in the armature. The structure is complex, but it is conducive to the design of small, lightweight motors, with at least 70 percent of the magnetic flux produced in the coil linking the armature and thus producing rotational torque. The design can be readily scaled up for large output. The NbTi superconducting field winding is an air-core coil that can produce an axial field of 5 or 6 tesla (T). The coil is equipped with a detachable power lead and a persistent current switch, and after excitation the coil operates in the persistent current mode. The magnetic shield reduces the external stray flux and also orients the field generated in the winding for effective linkage with the armature. The current collector is between the rotating armature and the stationary stator drum and feeds the armature. The weight and volume of a large superconducting motor or generator need be only one-half or less that of a conventional motor or generator. The authors recently toured Japanese superconductivity laboratories and companies, with our focus on motors, generators, and power handling applications. Two of us (Aprigliano and Arora) have been long engaged in materials development for ship superconducting electrical propulsion systems, so we begin there.

In 1969, led by the David Taylor Research Center, the U.S. Navy began developing superconducting ship electric propulsion systems (Ref 1). Superconducting drive will reduce ship size, weight, and fuel consumption. Furthermore, in an electric system the generator need not be in line with the motor drive, or even on the same deck, thus allowing new flexibility in arrangement of ship machinery. The first complete system, consisting of a turbine-driven 300-kW superconductive homopolar generator supplying power to a 400-hp superconductive motor, was constructed in the early 1970s. The system was installed on the test craft *Jupiter II*, and on 23 September 1980 she became the first vessel in history to be propelled by a completely superconductive electric drive. A 3,000-hp system was installed on the *Jupiter II* in 1983. A gas turbine-driven, oil-cooled, rectified alternator supplied power to a 3,000-hp superconductive homopolar motor. In the *Jupiter II* design the magnetic field of the superconducting NbTi solenoid was five times more powerful than the field in a comparable conventional motor. Because of ac losses in the rotor due to the time-varying current, ship superconducting motor programs, at least at present, are not incorporating superconducting rotors. For the same reason the homopolar motor has been preferred; in the multipolar design there are ac losses in the field windings because the armature current varies with time.

Efforts to develop superconductive electric ship drive are by no means restricted to the United States; Japan is very active. While the U.S. effort, funded by the Navy, focuses on military vessels, the Japanese program derives most of its support from the shipbuilding industry, either individually or through its organization, the Japan Foundation for Shipbuilding Advancement (JAFSA). Consequently Japanese efforts are heavily weighted toward commercial shipping. Different goals shape different design criteria. For example, the U.S. military emphasis on robustness against sea-battle shaking and jarring and on low noise generation is not a primary consideration for the Japanese, who stress ship speed, efficiency at partial load, and high maneuverability with large displacement for particular commercial niches they discern (such as short time cargo transit between Japan and the United States, icebreakers, and partially submerged cargo vessels).

Since 1979 Sumitomo Heavy Industries Ltd. has been working on a ship superconducting electric propulsion system (Ref 2). The company, in collaboration with former employee Prof. N. Takarada, now of the Department of Naval Architecture and Ocean Engineering, Yokohama National University, built a small prototype in 1982 and is now working on a 600-hp homopolar motor. The complete system consists of a homopolar generator (for large current supply) to drive the motor, with superconducting magnet windings in both machines.

Current feeders and collectors are the outstanding serious problem in both the U.S. and Japanese superconducting high power motors. In the Sumitomo 600-hp motor the current density at the collector is 200 A/cm^2. The Sumitomo motor now under development has metal-impregnated carbon fiber brushes. However, because of the severe problems of wear of the armature at the contacts and lifetime of the brushes, Sumitomo executives believe that they must improve the current collectors in order to build a practical motor.

Based on the 600-hp motor experience, Sumitomo Heavy Industries will develop a motor for a 50-knot freighter now under design. The ship will be able to carry cargo from Yokohama to San Francisco in 8 to 10 days. The company also plans to build a 3-meter-diameter dc homopolar superconducting motor to run at 100 rpm and deliver 20,600 kW. The superconducting dc homopolar generator to drive it will turn at 3,600 rpm and generate 21,500 kW. (Recall that 1 kW = 1.34 hp.)

MAGNETOHYDRODYNAMIC SHIP PROPULSION

Another way to propel ships by means of superconductivity--or rather by the large magnetic fields produced by superconducting coils--is by magnetohydrodynamics (MHD). The Japanese refer to this scheme as the electromagnetic thruster (EMT). An electric charge moving in a magnetic field experiences a force, the Lorentz force referred to previously. This force is perpendicular to both the magnetic field and the direction of motion of the charge. Imagine a ship with submerged, internal but open-ended, bow to stern tunnels along its axis, so that seawater can flow freely back through these channels as the ship moves through the water. Magnets and electrodes are distributed along the channels. The magnets generate magnetic fields in the channels and the electrodes, connected to a voltage source, induce dc electric currents in the conducting seawater. The magnetic fields and currents are in a plane normal to the axis and are arranged to be perpendicular to each other. The Lorentz force on the water carrying the electrical current then thrusts the water aft along the channels and the reactive force pushes the ship forward. There are no moving parts, no mechanical friction, no noise or vibration except that of the flowing water. Construction is simple and should be maintenance free. Thrust force transforming efficiency, defined as the ratio of water flow momentum change to Lorentz force, is over 95 percent. But overall efficiency is low; a major limitation is the low electrical conductivity of water. However, efficiency increases as the square of the magnetic field strength, and so superconducting magnets are a natural. To be commercially competitive an EMT vessel will require much higher magnetic flux density--about 20 T. NbTi and Nb_3Sn wires at 1.8 K are capable of creating those flux densities, but the stress on the material is tremendous. MHD ships will fill special roles. The Japan Foundation for Shipbuilding Advancement in 1985 organized a Research and Development Committee for Superconductive Electromagnetic Propulsion of Ships (Ref 3). A project is now in progress to develop a ship propelled by an electromagnetic thruster (Ref 4). Demonstration tests are scheduled for 1990. The ship will have a displacement of 150 tons, a propulsive thrust of 8,000 newtons, and a speed of 8 knots.

Professor Eiichi Tada of Osaka University, in collaboration with personnel and faculty of Osaka Prefectural Industrial Research Institute, Kobe University of Mercantile Marine, and JAFSA, has performed much research on MHD ship design. A superconducting thin film for the shielding of magnetic fields has been developed by sputtering an NbTi alloy onto an aluminum foil (Ref 5). Tada and associates designed the first full-scale EMT icebreaker (Ref 6). They are working on dipole magnets for the

EMT experimental ship (Ref 7). The flat coils of the thruster magnets are subject to extremely large electromagnetic forces, which must be transmitted to external supports. Adequately strong conventional collar supports are excessively heavy. A better design is needed. Dipole and double layer pancake magnets now under study produce fields of 2 to 4 T. M. Hiroi and the Tada group have studied anodes for superconducting electromagnetic ship propulsion (Ref 8) and the effect of magnetic fields of 5 T on the electrolysis of seawater (3.5 percent NaCl solutions) (Ref 9). The imposed magnetic field was observed to increase the oxygen evolution efficiency. The effect is small but favorable for the MHD thruster, since it reduces chlorine evolution.

ELECTRICAL POWER NETWORKS; SUPERCONDUCTING SYNCHRONOUS GENERATORS

For power handling, dc synchronous motors and generators are superior. Again, the 5- to 6-T fields (2- or 4-pole) generated by the large currents superconducting wires are capable of carrying, compared to the 1 to 2 T in generators with conventional copper windings, make possible a reduction to less than one-half the size and weight. Because of the zero electrical resistance of the superconducting coil, efficiency is increased. While the efficiency of a conventional 1,000-MVA generator is 99.0 percent, that of a superconducting generator of the same power is 99.5 percent. An improvement of 0.5 percent may not sound like much, but over the lifetime of the generator it is enough to pay for its entire cost.

In power handling, the low impedance of the superconducting generator is an important advantage over a conventional generator. The consequently longer response time provides stability to the power network, with its rapidly fluctuating load. T. Nitta, T. Okada, and coworkers at Kyoto University have built and tested a small (20-kVA) experimental superconducting generator (Ref 10, 11). Nitta and Okada (Ref 12) connect their 20-kVA generator and a conventional generator of the same rated voltage and capacity to a simulated regional power system. The time constants of their superconducting generator, with its large magnetic flux storage, are 10 to 20 times those of the conventional generator. In both transient response and steady state, Nitta et al. report that the voltage stability and power system stability of the system are much better with the superconducting generator. Increased network stability will allow designs with less margin. This should result in significant capital cost savings. In collaboration with the Kansai Electric Power Company and Toshiba, Nitta et al. (Ref 13) next designed and have been testing a 100-kVA experimental superconducting generator, Hesper-1, for electrical power networks. Emphasis is on "high response excitation" to enhance power system stability against transients. Previously designed superconducting generators operated at constant voltage. But to be useful in a practical power system the generator must be capable of controlling output voltage. Output voltage is controlled by quickly changing the current in the rotor coil as the generator's voltage changes in response to voltage fluctuations in the transmission line. (In this design the superconducting coil is installed in the huge thermos-bottle-like rotor.) Superconducting wires with low ac loss need to be developed. Under MITI's Moonlight Project the 8-year program (begun in 1988) is aimed toward development of a 70-MVA prototype and a 200-MVA pilot superconducting generator.

We have mentioned that in the motors and generators now being designed only the solenoid generating the magnetic field is superconducting. Looking to the fu ure, T. Ishigohka of Seikei University and M. Yamamoto of Takushoku University are investigating the characteristics of a full superconductor generator--rotor and stator--as well as a number of other topics relevant to superconducting electric drive machines (Ref 14). To circumvent the ac or time-varying current loss in the armature a damper is needed. However, when a cold damper is used the power dissipated in the damper is a heavy drag on the always expensive and inefficient liquid He refrigeration, and when a warm damper is considered the thermal design becomes complicated. A solution is to rotate the coils generating the field (as in Hesper) and for the armature winding, with its high ampere-turns, to be the stator. The synchronous and transient reactances then become large. The superconducting solenoid coils on the rotor can then be designed with only a weak damper. Ishigohka and colleagues have also concerned themselves with materials used in superconducting machines (Ref 15, 16) and various phenomena relevant to superconducting machines and transformers (Ref 17-20).

SUPERCONDUCTING MAGNETIC ENERGY STORAGE

When Kamerlingh Onnes discovered that the resistance of mercury and several other metals dropped at low temperatures below any value he could measure by standard resistance measurements, he set out to demonstrate that the dc resistance of a superconductor is in fact truly zero (or to state it more precisely, immeasurably small). A current in a ring or coil of self-inductance L and resistance R decays exponentially with time, with time constant L/R. (The energy stored in the ring is proportional to L and the dissipation by Joule heating is proportional to R.) Time constants of coils at room temperature are about 0.1 second, more or less independent of the size of the coil since both the inductance and the resistance scale with the number of turns or the length of the wire. Onnes and others were able to maintain persistent currents in superconducting rings for longer than 2 years. The zero resistivity of superconductors is the best known physical quantity--less than 10^{-23} ohm-cm. In comparison, the resistivity of the purest copper at liquid helium temperature is 14 orders of magnitude larger, about 10^{-9} ohm-cm.

The method Kamerlingh Onnes hit upon is that now used in superconducting magnetic energy storage (SMES). Electric power demand constantly fluctuates, and varies in the course of a day, and the variation changes with the season. But electric power generators operate most efficiently at constant power output. Therefore, energy storage plants are required. Many schemes have been proposed, but at present pumped hydroelectric power is the most commonly used. Superconducting magnetic energy storage was first suggested in the late 1960s by the French engineer M. Ferrier. In 1972 Boom and Peterson (Ref 21) of the University of Wisconsin proposed and patented the scheme that is the foundation of present day technology. Their scheme is basically the Onnes plan of a superconducting solenoid with a persistent current switch, but instead of a battery the design utilizes thyristor convertors connected to the ac line to charge and discharge the very large superconducting coils. The Electric Power Research Institute (EPRI) issued in 1984 an influential study endorsing SMES as commercially highly attractive (Ref 22), and in the same year the Department of Energy and Bonneville Power Administration constructed the largest SMES pilot plant yet tested, an 8-kWh coil for use in transmission line power stabilization. The Americans and Japanese (and the French, Koreans, Russians, West Germans, and Canadians) plan bigger efforts. The Japanese Research Association of SMES now coordinates and funds development in more than 40 large companies.

To reinforce with metal supports a coil carrying such huge currents would require millions of tons of metal and would be prohibitively expensive. Instead a doughnut-shaped coil perhaps 1,000 meters in diameter, wound with superconducting wire, will be buried deep underground in bedrock strong enough to withstand the vast electromagnetic forces on the coil. Convertors will transform the ac of the power line to dc in the coil, and the reverse for reversion to the power network. A 5-GWh SMES can put out about 1 GW of power. The coil current is about 700 kA, with an inductance of 70 H, and produces a peak magnetic field of 7 or 8 T. Conversion efficiency is 95 percent and overall efficiency, from ac input to ac output, is 90 percent, whereas the efficiency of pumped hydroelectric storage is only 70 to 75 percent. In the future it may not be necessary to convert between ac and dc. Superconducting power transmission lines and cables promise to be commercially viable, particularly at high power ratings (because of the cost of He cooling and insulation). Since these will be dc, they will link naturally to SMES installations. A high voltage dc power transmission line (not superconducting) is already in place in Japan, under the strait between Hokkaido and Honshu.

Another remarkable and attractive feature of SMES is response time. In contrast with hydroelectric energy storage, which is mechanical and slow, SMES systems can switch from charge to discharge and back in a few milliseconds. This is why SMES is attractive to stabilize electric power generation and transmission networks against transient and steady state oscillations. In a long distance power transmission system, undamped power oscillations tend to occur, even in "steady state" operation. Impelled by their interest in the synchronous superconducting generator (Ref 10-12), T. Nitta, T. Okada, and their coworkers at Kyoto University investigated the stability of a simulated power system with a small model SMES and their superconducting generator (Ref 23). The superconducting magnet was connected to the generator by two thyristorized bridges connected in series as a convertor. This was connected to the ac transmission line by two transformers. Both ac active power and reactive power were controlled. Complex harmonics are generated by the interaction of the SMES with the generator and power system both in charging and discharging. Filters were then introduced (Ref 24). Nitta et al. conclude that with filters good power control can be achieved, the current harmonics in the transmission line can be reduced to acceptably small levels, and the terminal voltage of the SMES can be held almost constant. An active filter utilizing a superconducting magnet is more effective than passive filters. These conclusions are confirmed by computer simulation (Ref 25).

Y. Murakami and his group at the Laboratory for Applied Superconductivity of Osaka University have also been active in the study of the stability of power transmission systems with SMES (Ref 26-30). A model system was designed to simulate the behavior of a long distance bulk power transmission system with voltage of 500 kV, capacity of 2,000 MVA, and length of 280 km (the distance from Osaka to Tokyo is 550 km). The conclusions of the Murakami group parallel those of Nitta et al.; the stabilizing effect of SMES is powerful, exceeding that which is practical with a Static Var Compensator, for example. With the SMES located at the generator bus, the best location, active and reactive power control with SMES increased the upper limit at which the power system remained stable by at least 50 percent, the maximum the particular experiment was able to test. Computer simulation confirms the experimental findings.

Often hydroelectric power is generated at a series of dams and generators along a river, perhaps high in the mountains and far from the user. The Osaka group has studied by computer simulation a system of 26 hydroelectric power generators, linked together and delivering about 500 MVA of power far downstream by a long transmission line (Ref 30). Again the simultaneous control of active and reactive power is able to damp out quickly an assumed swing in voltage and power.

SUPERCONDUCTING TRANSFORMERS

The superconducting transformer, a French idea, has been the object of intense development in Japan. The dual goal is to reduce transformer size and reduce electrical loss. Superconducting wire will be used in both the low and high voltage windings. The weight can be one-half to as little as one-fifth that of a large conventional transformer. The efficiency of conventional transformers is 99.7 percent, a loss of 0.3 percent. Through the introduction of ultrafine NbTi filament conductors, now commercially available and to be discussed below, loss can be reduced by one-half. The superconducting transformer, a large market item, will be commercially viable.

To cool the massive iron core to 4 K and keep it at that temperature in spite of thermal leaks and magnetic hysteretic power dissipation in the core (about one-fourth that in the superconducting windings) requires a great amount of expensive liquid helium. The iron core can be either thermally isolated from the windings and run at room temperature or done away with entirely. An air core transformer is unconventional but not as disadvantageous as it at first seems, since iron saturates magnetically far below the fields produced by the superconducting windings.

SUPERCONDUCTING WIRE

Superconducting wire is the thread that runs through this report. The basic parameters of critical temperature (T_c), upper critical field (H_{c2}), and critical current density (j_c) of NbTi, Nb_3Sn, V_3Ga, Nb_3Al, and Nb_3Ge are superior to those of other alloys and compounds. These and partially substituted alloys based upon them are the materials of which superconducting wires are made. For dc applications such as for dc magnets and coils the technological considerations and optimizations are different than for ac applications, such as for transformer windings, pulsed magnets, and motor and generator armatures.

The ac loss occurs both intrinsically in the wire material and because of vibration and friction. Vibration loss is reduced by fixing the wire securely in epoxy. Within the wire there is hysteresis loss in the ac cycle, coupling loss at interfaces between the superconductor and the bonding matrix, and eddy current loss. Hysteresis loss, a major contributor, is proportional to conductor diameter at low magnetic fields (and decreases monotonically as the diameter is decreased at all field strengths). Hence ultrafine superconducting filaments are embedded in normally conducting matrices. For several years wires have been commercially available containing NbTi and Nb_3Sn filaments 0.3 to 0.5 micron in diameter. As noted in the previous section, 60 Hz ac loss in these wires is already tolerable. But progress continues. Wires will be available with 0.1-micrometer-diameter filaments.

When a flux line moves (under the Lorentz force again) it dissipates energy. This heats the wire locally and can quench the superconductivity disruptively and sometimes catastrophically. Magnetic instability is avoided by sheathing the filament in a matrix of copper, aluminum, or a copper-nickel alloy; bundling bunches of filaments around a small central copper core--10 or 15 thousand filaments in all--into a wire; and twisting the wire with a pitch of about 1 mm. The diameter of the wire must be small so that the pitch can be as tight as possible. The high resistivity of the copper-nickel alloy matrix reduces bonding loss at the superconductor/matrix interface.

Someday in the future high temperature ceramic superconductors will come into their own, and superconducting magnets, motors, and transmission lines will be operated at liquid nitrogen temperature, if not at room temperature. But for now the workhorse of technical superconductivity, for high current/high field (not electronic) applications, is NbTi. For producing the extremely high fields needed in plasma fusion, materials with the highest possible critical fields and critical current densities are needed. Nb_3Sn has a higher critical field but is more brittle and difficult to fabricate. These compounds and V_3Ga and Nb_3Al are fabricated at the National Research Institute for Metals (NRIM). To make Nb_3Sn filaments, Nb rods are embedded in a Cu-Sn alloy, cold-worked into a wire, and heat treated. The brittle Nb_3Sn sheathing the Nb cores is protected and supported by the ductile Cu-Sn matrix. Sekine and coworkers (Ref 31, 32) discovered that the addition of 1 percent of Ti to the matrix greatly increases the formation rate of the Nb_3Sn sheath and increases H_{c2}. The increase in H_{c2} comes from an increase of the normal state resistivity by the transition metal additive.

Nb_3Al has an even higher upper critical field (30 T at 4.2 K) but cannot be made by the above "bronzing" process because the intermetallic compound is not thermodynamically favored. K. Inoue, T. Takeuchi, and the NRIM group (Ref 33-37) have found a way to fabricate ultrafine multifilament Nb_3Al wire using Al-based alloy cores hardened by the addition of Mg, Cu, and Zn. While Al is soft, the Al-Mg alloys have a hardness close to that of pure Nb. The Al-Mg alloys can, therefore, be drawn into wires without breaking, as frequently occurs when pure Al cores are used. Alloys of Al with 5 to 10 at. % Mg are swaged into 7-mm rods. The rods are inserted into close-fitting niobium pipes and the single core composites are cold-drawn into 1.4-mm-diameter wires and cut into short pieces. In the NRIM construction, 110 of these short wires are packed into a Nb pipe, cold-drawn into wires, cut again into short pieces, inserted into Nb pipes, and drawn. Through repetition a wire of about 0.7-mm diameter containing 1,331,000 (110^3) filaments is obtained. The wires are heat treated, first at 900 °C and then at 700 °C, to form Nb_3Al along the filament surfaces through a diffusion reaction between the Al-Mg cores and the Nb matrix. The critical temperature of the wire is 15 to 16 K, the upper critical field at 4.2 K is 21 to 23 T, and in a field of 10 T at 4.2 K the critical current density is 1 to 1.5 x 10^5 A/cm^2. These characteristics exceed those of NbTi and are comparable to those of commercially available Nb_3Sn wire. The ac loss approaches the theoretical lower limit. Nb_3Al multifilament wire, easier to work with and cheaper to make than Nb_3Sn, is very promising for practical high field superconducting cable. The wire is being commercialized by Furukawa Electric Co., Hitachi Cable Ltd., and Showa Electric Wire Co.

At the Electrotechnical Laboratory, T. Onishi (Ref 38, 39) has developed a three-component cable for dc and pulsed magnets. Multifilament NbTi/Cu/CuNi wire of 0.3-mm diameter containing filaments of 22-micrometer diameter is twisted to a twist pitch of 10 mm. Four of these strands, clad with CuNi, and three high purity Al wires are then twisted together with a pitch of 10 mm, solder-filled, and compacted through a die. Six of these subcables are next twisted around an insulated CuNi wire. In the final cable 15 of the previous subcables are twisted around an insulated stainless steel strip, which helps to support the electromagnetic stress. In pulsed operation the ratio of loss to energy stored in the 6.6-T field is about 0.08 percent, for a field cycle of zero to 6.6 T to zero in 3 seconds.

In 1897 the House of Sumitomo established a copper rolling works to manufacture copper wire. Today Sumitomo Electric Industries makes not only electric wire and transmission cable but steel wire and construction rods, optical fibers, carbide and ceramic tools, powder metallurgy electrical contacts and heat sink metal, synthetic diamond and cubic boron nitride tools, disc brakes, fuel cells, and hundreds of other products. They are among the world's leaders in making high critical current density, high T_c ceramic films. And in spite of the saturated market for Nb-alloy superconducting magnet wire, Sumitomo Electric has recently expanded its plant. Their hot extrusion, composite billet facility is the largest in the world. For dc magnets for magnetic resonance imaging and magnetically levitated trains the wire consists of 1,000 30-micrometer NbTi filaments embedded in oxygen-free copper. For persistent current switches a high resistivity Cu-Ni matrix is used. A mixed Cu/Cu-Ni matrix is employed for use in pulsed or ac magnets. Wire with Nb_3Sn superconducting filaments is also being produced. The company makes magnets as well as supplying wire and cable.

CONCLUSION

It is evident that, as in superconducting electronics and in high T_c ceramics, the Japanese are active in every application of the Nb-based superconductors to ship motors and generators, to synchronous motors and magnets for power handling and network stabilization, to commercial development of magnetohydrodynamic ship propulsion, to transformers, and to dc and pulsed magnets. High T_c notwithstanding, the Japanese Government continues to back research in conventional superconductivity, and to an even greater extent so does Japanese industry. With the advent of high T_c ceramics, Japanese funding of conventional superconductivity actually increased. The high level of intelligence and competent management of superconductivity research and development within the Ministries (Monbusho, MITI, and STA) and the high level of cooperation and mutual support between the Ministries, the faculty of engineering schools, the national laboratories, and Japanese industry, all assiduously directed toward producing salable products, typify Japanese management of engineering.

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OVERVIEW OF REMOTE SENSING ACTIVITIES IN JAPAN: EARTH OBSERVATION PROGRAMS

Ralph N. Baker

The Japanese have made impressive strides in establishing a first-rate remote sensing capability and cooperate closely with members of the international remote sensing community. Visits to the National Space Development Agency of Japan (NASDA) and three technical image processing and applications centers demonstrated capabilities on par with those of the western nations. Primary developmental efforts are directed toward improved processing techniques and an expansion of applications, in preparation for the impending launch of next-generation earth observation satellites.

INTRODUCTION

Four centers of remote sensing technology in Japan were visited in mid September 1989. Technical managers and scientists at these centers were interviewed to (1) review Japanese progress in remote sensing satellite technology, earth monitoring applications, and image processing; (2) identify key groups, their capabilities and research goals; and (3) highlight aspects of the Japanese progress in the field of potential interest to the Office of Naval Research Far East (ONRFE) for future exchanges of information and cooperation.

The following comments are based on personal interviews, visits to the facilities, and contributions of the centers to the scientific literature (see the references). The support of Dr. A.F. Findeis, Director, Sandy Kawano, Editor, and the ONRFE staff is gratefully acknowledged.

STATE OF THE ART - SHORT SUMMARY

Remote sensing applications of potential interest to Naval activities include (1) surveillance and object detection, including ship wakes, oil seeps and slicks, and indirect seafloor mapping (bathymetry); (2) oceanography and weather prediction; and (3) worldwide communications, which will not be addressed in this review.

Research aimed at improving remote surveillance and oceanographic/weather monitoring capabilities trends toward better images through higher spatial and spectral resolution, often combined with broader spectral coverage and multiple or multispectral imaging.

The ability to detect and recognize objects on the earth's surface calls for a picture element ("pixel") small enough to uniquely define the object or make it partially recognizable through pattern matching. Pixel cells may range from 100 meters to 1 km for the regional mapping of ocean currents or weather patterns to 5 or 10 meters for detecting man-made structures. In addition to identifying an object by pattern or geometry, the recognition of a "spectral signature"--composed of energy emitted by or reflected from the object--will often describe a unique spectral response when enough measurements are taken at different wavelengths within the electromagnetic radiation (EMR) spectrum.

This unique signature, composed of measurements taken over a series of discrete wavelengths, is often combined with pattern or geometry to classify an object by size, shape, texture, and even composition. While materials of similar composition may overlap in their spectral character, the ability to sample (measure) their unique response curves at many narrow channels over a broad spectral range enhances their differences and thus their detectability.

Remote sensing technology then strives to improve the "detail" or spatial resolution of an object for more accurate identification, as well as its spectral resolution, pushing into both lower and higher parts of the spectrum, to detect subtle but important differences in the basic compositions of things. Since greater spatial and spectral resolution requires more pixels per image and consequently higher data rate transmissions from the satellite, data relay and processing capabilities must also be improved to convert the raw data into useful operational information. One way to do this is by data compression, a relatively new technique where the data stream is periodically resampled and recombined with some acceptable loss in image quality at manageable (i.e., affordable) data rates; another is to register data sets, which by themselves are limited but have useful attributes when used in combination. Consider, for example, a relatively low resolution "many banded" or multispectral image combined with a higher resolution but single band image of the same area, thereby gaining the advantage of greater *spatial* detail combined with broad *spectral* coverage. Variants of these techniques will include multispectral thermal infrared or active microwave sensors, where the spectral response curves of target materials at these longer wavelengths can be compared to known target signatures and used as detection aids.

These techniques rely on powerful digital image processing systems that (1) cosmetically restore bad data cells or scan lines; (2) geometrically "warp" the image to an operational map scale and projection; (3) improve image information by suppressing or enhancing selected spectral signatures, i.e., filtering high or low frequency noise; and (4) mathematically manipulate combinations of spectra by individual pixel or spectral group to aid identification by the interpreter. For a review of current image processing technology, see References 1 and 2.

A major effort has been initiated by industry, with the support of several governmental agencies including ONR, to use new generation remote sensing satellites and supplementary "ground truth" data to improve offshore detection (objects, seeps) and sea bottom mapping. This Gulf Offshore Satellite Applications Project (GOSAP) (Ref 3) is being undertaken by members of the petroleum and marine industries to determine how best to use remote sensing to address practical problems faced by these industries. Primary among these objectives, the GOSAP team will evaluate the potential for satellite offshore exploration using combined satellite and "sea truth" data sets.

The remote sensing objectives of this 2- to 5-year study will compare sea surface spectra from satellites (ERS-1, Radarsat, SPOT, Landsat) with water column and seafloor measurements from instrumented fixed and mobile platforms in the Gulf of Mexico, with the aim of establishing repeatable correlations between surface and seafloor. The Japanese Earth Resources Satellite (JERS-1), to be launched early in 1993, will contribute an important data set to the project, and the Japanese see an application of the study to their own environmental and exploration activities in the Inland Sea.

Initial test sites will be selected over known oil production and heavy tanker traffic in the Gulf of Mexico, and extensive measurements will be taken above, at, and below the sea surface to determine how best to image the seafloor or detect oil seeps from orbital altitudes. Already, preliminary correlations have been made relating sea surface depressions with low density salt domes in the subsurface.

The potential correlation of satellite-collected sea surface signatures, oil seeps, and seafloor topography will allow mariners and geologists to extend these techniques into frontier areas.

The project will involve cooperation between government agencies, industry, and universities, who will each contribute to the data collection, image processing, or interpretation phases.

ORGANIZATIONS VISITED - RATIONALE

The Japanese space program enjoys the full commitment of the Government, has huge popular support, and has established itself as the "NASA of the Orient," on par with the original U.S. National Aeronautics and Space Administration and the European Space Agency (ESA) (Ref 4). The Japanese have matched their enthusiasm with financial commitment, where joint programs have already been announced with ESA and NASA in support of the space station, shuttle programs, and polar orbiting platforms. Further cooperation is under discussion and sure to occur, driven by the continuing dramatic advances in Japanese computer technology and avionics.

Much of this progress has been in remote sensing technology, where the recent launches of earth monitoring satellites MOS-1 (marine observation satellite) and GMS-4 (geostationary meteorological satellite) testify to the technical maturity of their programs.

Since the main research thrusts are largely sponsored and directed by the Government, the National Space Development Agency of Japan (NASDA) and subsidiary agencies, Remote Sensing Technology Center of Japan (RESTEC) and Earth Resources Data Analysis Center (ERSDAC), were selected to best represent Japanese remote sensing technology. The Japex Geoscience Institute, a subsidiary of Japan's National Oil Company, leads the country in the application of remote sensing technology to earth monitoring from space. Other organizations, e.g., the Meteorological Research Institute, Tsukuba City, and the Earth Observation Center, NASDA's ground receiving facility, should be visited in the future.

Each of the groups visited are active in the international remote sensing community, have ongoing research programs, and are adequately funded and equipped. Contacts listed in Table 1 should be revisited periodically to keep abreast of the rapidly changing technology and the leadership role Japan is taking in it.

Table 1. Remote Sensing Organizations Visited in Japan, 11-23 Sep 1989

Name	Type	Address	Key Contact	Function
National Space Development Agency of Japan (NASDA)	Governmental agency	World Trade Center Bldg 2-4-1 Hamamatsu-cho Minato-ku, Tokyo 105	T. Tanaka Director Earth Observation Program Office Tel: 03-5470-4252 Fax: 03-432-3969	Develops and implements Japan's space activities
Remote Sensing Technology Center of Japan (RESTEC)	Private, nonprofit, partially funded by industry, guided by NASDA	Uni-Roppongi Bldg 7-15-17 Roppongi Minato-ku, Tokyo 106	K. Maruo Managing Director Tel: 03-403-1761 Fax: 03-403-1766	Conducts research and development into remote sensing, contributes results to economic development, etc.
Earth Resources Satellite Data Analysis Center (ERSDAC)	Supported by Government and private industry	No. 39 Mori Bldg 2-4-5 Azabudai Minato-ku, Tokyo 106	J. Komai General Manager Tel: 03-433-7636 Fax: 03-433-2520	Promotes remote sensing technology for application to resources exploration
Japex Geoscience Institute (JGI)	Private industry, subsidiary of Japan Petroleum Exploration Co. (JAPEX)	Akasaka Twin Tower 2-17-22 Akasaka Minato-ku, Tokyo 107	H. Watanabe Manager Remote Sensing Section Tel: 03-584-0511 Fax: 03-584-0563	Geophysical and remote sensing surveys for exploration, R&D into remote sensing techniques, external consultants

RESULTS OF THE VISITS

National Space Development Agency of Japan (NASDA)

NASDA is Japan's national space agency, similar to NASA and ESA. It is responsible for planning and implementing Japan's space activities, which include the design and development of launch vehicles, satellites, tracking facilities, and control systems (Ref 5). NASDA will expand its earth observation program in 1993 with the launch of "Earth Resources Satellite-1" (here called JERS-1 to distinguish it from a similar satellite to be launched by ESA in early 1991). Other recent satellites dedicated to earth observations include MOS-1*, soon to be joined by MOS-1b in 1990, and GMS-4, launched in September 1989 after experiencing problems with the main launch vehicle.

NASDA operates under the direction of the Government's Space and Technology Agency, which is guided by the Space Activities Commission and Ministry of Transport, Post, and Telecommunications.

NASDA is internally organized into five space centers (which include earth observations, propulsion, tracking, and control), four tracking stations, and five liaison offices, operating with a total budget of ¥1,137 hundred million (about $790 million) in 1988. Of this, earth observation programs account for about 25 percent. Total employment has reached 938, of which 40 percent (est.) are professional scientists and engineers. Both the budget and staff continue to grow, despite a severe competition for funds, as the space program gains momentum and recognition in the international space community.

* Complete descriptions of the MOS, GMS-4, and ERS satellites are found in NASDA publications 4/5T (1988) and 10/10T (1989).

Special Capabilities. Like NASA, NASDA has a full range of space-related capabilities scattered among various centers and stations. Since the national commitment to a space leadership role is both relatively recent and serious, NASDA facilities are modern and equipped with the latest technology from Japanese industry (Ref 6). These centers are expanding in anticipation of Japan's full-fledged participation in space, with plans ranging beyond earth observation satellites to the space station, a hypersonic space plane, and eventually a Japanese space shuttle "free flyer."

Research Directions. In the near term NASDA is heavily committed to earth observations through unmanned satellites, the first of which is MOS-1, launched in 1987 in response to the national space policy established by the Space Activities Commission of Japan.

MOS-1 carries three radiometers, which sense naturally emitted energy from the visible, near and thermal infrared (IR), and microwave parts of the spectrum (Ref 4). These sensors monitor air and ocean currents, cloud movements, ocean temperature, sea surface roughness, and snowfall. The spatial resolution of the sensors ranges from 50 meters to 23 km, which combines the capabilities of "Landsat-like" 50-meter resolution (in the visible and near IR spectrum) with typical low resolution but wide coverage weather satellite capabilities in the thermal IR and microwave regions. MOS-1 serves the weather and oceanography communities well in places (such as Japan) where data are accessible on a real time basis. For other applications like object detection or surveillance, MOS-1 is of limited use because higher resolution imagery (e.g., 10-meter panchromatic data from the French SPOT program) is available elsewhere.

The GMS-4 (Ref 4) was launched in September 1989, the latest in this series jointly developed by NASDA and the Japan Meteorological Agency. The GMS series consists of stationary weather satellites that form part of the World Meteorological Organization's global weather watch program. As such they carry visible and infrared radiometers designed to observe large scale weather patterns at resolutions of 1.25 to 5 km. Unlike the MOS-1, they carry no corresponding high resolution sensors in the visible and near IR bands.

The JERS-1 has captured the interest of the international remote sensing community for its promised capability to image the earth at high (<20 meters) resolution in eight optical (0.56 to 2.33 microns) and one microwave synthetic aperture radar (SAR) band (Table 2). Included in the array is a duplicate near IR channel for down-track stereo imaging to provide three-dimensional analyses of presently "flat" imagery. This capability will allow scientists to study the earth using new combinations of spectral bands, in stereo, at the same scale and format. In addition, detailed textural information provided by the SAR will complete an unprecedented set of common-base data for the interpreter, whatever the goal.

JERS-1 is scheduled for launch in early 1993, with the details of data access and distribution still under discussion by NASDA, the Science and Technology Agency (STA), and the Ministry of International Trade and Industry (MITI). Further into the future, NASDA has announced several additional earth observation research efforts.

The Advanced Earth Observing Satellite (ADEOS) program will follow JERS, probably early in 1994. This satellite will provide even more capabilities than its predecessor, featuring an ocean color and temperature scanner and advanced visible and near IR radiometer, covering 17 spectral bands at <20 meters resolution (Table 2).

The ADEOS program will also be used to develop a Japanese network of data relay satellites similar to the U.S. TDRSS system, which will give them real time global coverage. In addition, space is provided for a "sensor of opportunity" to be supplied by a foreign source.

Table 2. Sensor Capabilities: Advanced Japanese Earth Observation Satellites[a]

Earth Resources Satellite-1 (JERS-1), 1993	
• Combines optical sensor (OPS) with synthetic aperture radar (SAR)	
OPS	
Visible and near IR radiometer (VNIR)	3 bands
Short wave IR radiometer (SWIR)	4 bands
Stereoscopic - along track	1 band
Swath width	75 km
Ground resolution	18 m x 24 m
SAR	
Observation frequency	1,275 MHz
Swath width	75 km
Resolution (3 Look)	18 m x 18 m
Advanced Earth Observing Satellite (ADEOS), 1994	
• Flies advanced optical sensors	
• Sensor of opportunity	
• Modular concept in preparation for polar orbiting platform	
• Tests data relay and tracking satellite system	
Advanced Optical Sensors	
Ocean color and temperature scanner (OCTS)	12 bands
Advanced visible and near IR radiometer (AVNIR)	5 bands

[a] Information kindly provided by K. Maruo, Managing Director, Remote Sensing Technology Center of Japan, from "Remote Sensing Activities in Japan," *International Journal of Remote Sensing* 10(2), 395-410 (1989).

The range of sensors advertised should provide key data for research directed toward ocean seep detection and nearshore bathymetric mapping, as well as the more conventional weather and ocean measurements.

Other programs include the cooperative effort with NASA and the European Space Agency, where the Japanese will fly their own polar orbiting platform, in coordination with the international space station to be launched in late 1996.

The Japanese plan to fly their own space shuttle as early as 1992, an effort that will provide them with satellite launch, servicing, and retrieval capabilities as well as a platform for heavyweight earth observation sensors. In preparation for this, Japanese astronauts are already being trained by NASA and most recently with the Soviets, where two Japanese astronauts will shortly visit the Soviet MIR space station.

Overall, the visit to NASDA left an impression of serious commitment and national enthusiasm. NASDA has set out clear-cut goals, with the staff, facilities, and government funding to carry them out. Significantly, NASDA headquarters sits in the World Trade Center, lending access to commercial funds as applications develop.

Remote Sensing Technology Center of Japan (RESTEC)

RESTEC was established in 1975 as a nonprofit private foundation by NASDA, STA, and 26 industrial "sustaining members" that support its operation. These include major corporations such as Asahi, Fujitsu, Hitachi, Mitsubishi, NEC, and Toshiba. Its charter is to promote environmental protection and social, economic, and national welfare through the development of remote sensing technology. The center's major research interests are (1) the development of remote sensing technology, (2) the investigation of new earth resources applications, (3) improved and innovative data processing technology, and (4) the development of data analysis/image processing systems.

RESTEC is headed by a president (K. Suzue) who, with the guidance of a board of directors, consultants, and advisors, controls a series of departments through executive directors. These departments include research, software, data services, and investigations (among others). RESTEC staff numbers 80 individuals, 45 of whom are stationed at the Earth Observation Center's data receiving facility. Of the 80, 9 to 11 are professional scientists, with the rest technicians. The center staff is expanding, with a 7 percent increase in the total operating budget approved for FY90. Several of the staff were educated in Western Europe or the United States and are engaging in multinational remote sensing projects, although none appear to be particularly innovative at present.

The center has three main functions: data distribution, training, and applications research.

Collection and Distribution of Remote Sensing Data. RESTEC performs the same functions as the U.S. Earth Resources Observations Systems (EROS) Data Center run by the National Oceanic and Atmospheric Administration (NOAA). It maintains a facility open to the public whereby users query a worldwide image data base to determine what coverage is available for their area of interest. The center has recently gone to optical disk storage, which allows them to maintain a large image inventory in a limited physical space. This system is state of the art and includes an instant print device made by Sony that produces good (not outstanding) quality hard copy color prints directly from a cathode ray tube (CRT) display. RESTEC also has been distributing Landsat data to PC users on floppy disks since 1984, one of the first centers to do this. The facility has a comprehensive set of manuals, maps, and paper image prints for the public's guidance; most are in English and Japanese.

RESTEC will become, along with ERSDAC, the primary distributor of Japanese satellite data (RESTEC already distributes SPOT data in Japan); at present the division of responsibility (e.g., domestic versus international users) between the two is still the subject of lively debate between MITI and NASDA. Reportedly the Japanese will abide by the "open skies policy" practiced by the United States and Europeans (and at least partially by the Soviets) that guarantees worldwide nondiscriminatory access to satellite data.

Since 1987 RESTEC has had responsibility for the receiving and data preprocessing of NASDA's Earth Observation Center, a facility presently configured to receive Landsat, SPOT, and MOS data (the JERS-1 facility is presently under construction).

Remote Sensing Training Programs. RESTEC conducts remote sensing training courses, including applications and image processing techniques, for clients worldwide. A significant portion of the nondomestic users represent developing countries (e.g., Burma, Nepal, Bangladesh) that have turned to the Japanese rather than the more experienced remote sensing organizations in the West. This has been in part due to funding provided by the Japanese International Cooperation Agency, as part of a technical cooperation program for developing countries. Courses are taught at both basic and advanced levels and include lectures, tours, and hands-on experience on the RESTEC image processing systems. The training staff members are experienced and possess advanced degrees, having benefited by 14 years experience in Japan and by participating fully in the international remote sensing community. The training facilities are excellent, with an extensive technical library, a worldwide data set, and four separate image processing systems available.

In addition to the formal training programs, RESTEC publishes a quarterly technical newsletter that it distributes worldwide and conducts seminars and symposia related to applications development and image processing advances.

Facilities and Equipment. RESTEC occupies three floors of a modern office building near central Tokyo that house the data distribution/user services center, the training and conference rooms, and the image processing facility. Four separate image processing systems make up this facility; the first two, a Bendix "MDAS" and General Electric "Image 100," are obsolete and await disposition--probably to a university. RESTEC developed a PC-based system called ENDIPS (end users digital image processing system) designed for operation on the NEC PC-9800 series, and most of the student training takes place on it. In addition, a FACOM M-730/8 computer and display processor, an NEC MS-140 advanced RESTEC processing system, and a MELCOM 70 Model 50 "multispectral advanced RESTEC system (MARS)" round out the image processing capabilities. Some of these systems seem redundant and only two, the ENDIPS and MARS systems, were demonstrated during the visit. Peripheral equipment includes high resolution 1024 x 1024 pixel CRT displays and an Optronics C-4300 image recorder that converts digital bits from a product tape to a photo negative for printing. The image processing capabilities demonstrated are judged to be comparable to equivalent centers in the West; basic processing techniques demonstrated here have been well documented in the literature and are widely available. Advanced techniques, probably under development, could be considered proprietary or experimental and therefore not shown to visitors.

Applications Studies. The major thrust of the research at RESTEC involves developing new ways to solve earth-related problems from remote sensors. Applications include nonrenewable resources exploration; earth hazards (earthquakes, volcanoes) detection; land use planning; and agriculture, forestry, and marine (e.g., fisheries) studies.

Applications demonstrated by RESTEC rely heavily on the digital classification of multispectral images to represent various "themes," where each represents some natural phenomenon such as a vegetation type, ocean color, or land cover. This can be done in a supervised mode, where the computer spectrally classifies a training set of pixels that represent some chosen land cover type and then "recognizes" and color codes all other pixels in the total image population having the same spectral signature. It can also be done in an unsupervised mode, where the entire image is arbitrarily divided into a selected number of classes, based on their spectra (i.e., brightness or gray level). This can be illustrated as an incremental subdivision of a continuum of gray levels, ranging from black (zero response) to white (maximum response), assigned digital numbers, 0 = black (no spectral response) to 256 = white (total spectral response), in an 8-bit system where intervals of gray levels are grouped and assigned to a class. The end result is a colorful map where each color represents a "class" or gray level range which, by observation, is then related to some surface cover in the image. This differs from the supervised classification in that no training set of pixels is selected; the entire image is subdivided, by the brightness value of each individual pixel, into the major classes present.

Examples of projects using computer-based image processing techniques include land cover classification around Mt. Fuji and the Seto Inland Sea, crop yields, tree species studies, urban land classification in the Tokyo metropolitan area, and sea surface temperature studies using a NOAA thermal channel from the AVHRR sensor. Of these the latter study should have the most potential interest to ONR for regional oceanographic applications.

From these examples it is felt that RESTEC is currently underutilizing their image processing capabilities; there are more sophisticated techniques (e.g., principal components analyses, intensity-hue-saturation transforms, band ratio/contrast stretch combinations) that are widely known and within the limits of their processing capabilities. ERSDAC appears to be taking the lead in image processing research and both agencies could develop a cooperative program to their mutual benefit. This would fall logically out of NASDA's intent to make both RESTEC and ERSDAC data distribution centers for Japanese flown remote sensing data; possibly some cost and technical benefit could be achieved by their mutual cooperation in image processing.

Earth Resources Satellite Data Analysis Center (ERSDAC)

ERSDAC was established in 1981 under the sponsorship of MITI as a non-profit agency within the private sector. ERSDAC describes itself as a "catalyst which bridges government and industry" and is thus able to benefit from the advantages of each: stable funding and access to government data coupled with the acceleration of research and practical application encouraged by the profit motive of industry. Its main aim is to promote the use of remote sensing technology as it is applied to the exploration for nonrenewable resources. Despite this narrow aim, techniques developed can often be applied to signature detection, classification, and enhancement for use by other interests, including the marine community.

ERSDAC's organizational structure is similar to that of its sister agency, RESTEC, and many of its research goals and activities overlap. The president of ERSDAC, advised by a board of directors and various advisory committees, runs the organization through an executive managing director who, in turn, manages both an administrative and technical staff. The manager of the technical department, Mr. J. Komai, has direct responsibility for all of the remote sensing activities. The ERSDAC center is supported by a complicated "supporting organization," which includes various governmental ministries (Education, MITI, Environmental Studies), universities, the national oil and mining corporations, and others. Curiously, while ERSDAC appears in some organizational charts as supersedent to RESTEC, the staff numbers only eight professionals and five technicians as compared to RESTEC's total of 80. Of the eight ERSDAC professionals, one, Dr. Y. Ishiwada, is a former director retained on staff as a technical advisor. The probable difference is that ERSDAC is solely a research organization, while RESTEC is chartered to service the worldwide user community as well. Despite this difference in staff, ERSDAC, like RESTEC, will be responsible for distributing Japanese satellite data to either domestic or international users, which will require a significant increase in staff in the near future. Whether this will be accomplished through a transfer of funds within NASDA remains to be seen.

ERSDAC's major efforts to date have been to prepare a series of 40 case studies worldwide, encompassing all types of earth terrain, both onshore and offshore. Important areas of interest are the mapping of "lineaments"--faults or fractures in the earth's crust that could be the site of future earthquakes--and the automated recognition of rock and soil types for regional surface mapping. Both of these applications make heavy use of the Landsat thematic mapper (TM), which contains seven narrow spectral channels, including a thermal IR band, and SAR data that are digitally registered to the TM to provide an added textural dimension. They also produce apparent thermal inertia (ATI) maps from the Landsat TM thermal band for improved rock type discrimination. These studies demonstrate the breadth of ERSDAC's applications expertise and their familiarity with advanced image processing techniques.

Image Processing Techniques. ERSDAC's focus is on the development of new and innovative techniques that will ultimately benefit the nation. This they are doing very well, using a wide variety of data types and such advanced processing as mathematical rotations and transformations of three-dimensional signatures (where each three-dimensional axis represents one channel of a multispectral data set) in "spectral space." This technique, called principal components analysis, provides the maximum separation between signature groups, thus maximizing the ability to discriminate between them. Further, each of these spectral groups are assigned one characteristic of a selected color: intensity, hue, and saturation. The results are then merged or "transformed" in various combinations until the operator decides that the best enhancement of the image (and hopefully the optimum information content) has been achieved. Similar techniques have been developed for the processing of single channel SAR data; techniques for processing multispectral SAR and thermal IR are being considered and will be examined when these data sets become available from future satellites.

Digital terrain modeling was also demonstrated, where one of the three spectral bands making up the image is replaced by terrain elevation data (this is obtained from some preexisting map or public data base or can be computed directly from stereo satellite data). The combination of two spectral bands provides a two-dimensional "map" image while the terrain elevation data provide the "z" axis or third dimension. The resulting image represents a three-dimensional block model that can be rotated in space or modified interactively on the CRT display.

ERSDAC is also interested in data compression techniques and has applied them to principal components analyses with mixed results to date.

These techniques, while impressive, have been available for several years and are used routinely by most of the major western image processing centers.

Facilities. ERSDAC has two image processing systems, a PC-based TerraMar system partially developed by Japex, the national oil company, and a Fujitsu-computer-based system, both of which rely on an Optronics C-4300 color film writer to produce high quality color images. While not intended to be a public data repository like RESTEC, ERSDAC maintains an internal library of about 600 computer-compatible tapes (CCTs) of mainly Landsat (MSS and TM) and SPOT (panchromatic and XS) for research purposes. An interesting feature of this image library is an interactive data retrieval system, where a user can input geographic coordinates for an area of interest and see immediately on the CRT display a map showing data held for the area. This has usually been done in the past using path-row index maps and thick computer printouts or through a terminal request to a paper plotter, neither of which is time efficient.

Future Plans. Future research plans are to continue the development of image processing techniques in the short wave IR spectrum to detect volcanoes and thermal springs, initially using Landsat and SPOT imagery, complemented by other data, such as the space shuttle's large format camera (LFC), airborne SAR, and multispectral scanners. This is in anticipation of the launch of JERS-1, which will provide, as previously described, multiple spectral channels ranging from the visible through microwave parts of the spectrum. The processing of JERS and eventually ADEOS data will become the primary focus of ERSDAC. In preparation for these activities, ERSDAC has conducted an ERS-1 simulator study (Ref 6), which developed a method to simulate JERS-1 stereo images by computer, achieving 20-meter spatial resolution, then tested the technique on LFC images from the space shuttle.

Satellite stereo coverage has only been routinely available since the launch of SPOT-1 in 1986, although Landsat users for years have used overlapping images for partial stereo coverage. The ability to look at the earth's surface stereoscopically provides an important depth dimension to analysts, who can now map terrain features much more accurately.

As a personal comment, while all remote sensing groups visited in Japan were cooperative and displayed a high level of professionalism and scientific expertise, none could match ERSDAC for enthusiasm and professional energy. They are interested, active partners in the remote sensing community and undoubtedly will become a first class center of excellence.

Japex Geoscience Institute (JGI)

JGI is a wholly owned subsidiary of Japan Petroleum Exploration Company (Japex), established in 1983 to develop new ways to explore for petroleum resources. This goal partially overlaps applications research being conducted by ERSDAC, but one can conclude that results of the research conducted by JGI aren't necessarily made available to the public, as would be the case with ERSDAC. JGI does some of the image processing work for ERSDAC, so there is strong cooperation between the two groups. JGI's petroleum exploration efforts involve both the development of remote sensing and geophysical surveying techniques, and a substantial portion of the JGI staff has been transferred over from the parent oil company; thus the staff is very experienced in their particular area of interest. JGI has a total staff of about 250, which includes 130 scientists and engineers (only 9 to 10 of these seem to be directly involved in remote sensing research). This makes them the largest geophysical and remote sensing applications research group in Japan, a fact driven by Japan's critical need to develop new sources of petroleum to fuel its expanding economy.

Like the other groups visited, JGI is headed by a president (S. Kohzuki), who answers to a board of directors and who supervises several department heads. The remote sensing section lies within the Department of Geology, headed by Dr. H. Watanabe. Unlike ERSDAC and RESTEC, there is no supporting group of industrial associates and, therefore, no hard requirement to share results of the internal research with anyone other than the parent company. In addition, the group functions much like a U.S. consulting engineering firm, undertaking proprietary projects for commercial clients.

JGI maintains two field offices, one in Beijing, China, the other in Houston, Texas, cities near Japex's current international exploration interests.

Functions. JGI's business involves (1) contracted geophysical exploration surveys, (2) research and development of geophysical exploration techniques, and (3) design and manufacture of equipment related to the foregoing. The primary thrust of the remote sensing activities is in worldwide structural mapping, with image processing techniques (mainly spectral mapping) developed to support this effort. It is felt that much of the theoretical image processing work is being done at ERSDAC.

Facilities. The JGI remote sensing center occupies three floors in the Akasaka Twin Tower Building, central Tokyo. Image processing is done on an interactive system developed in-house and tied into an IBM 3090-200VF mainframe computer. This computer is shared with the seismic processing department, which could present potential priority problems. In addition to this primary system, JGI also has a DeAnza "smart terminal" driven by a PDP11/44 and a PC-based TerraMar system with 600 MB storage for routine terminal work. The TerraMar system, widely used in the United States, was partially funded and developed by Japex. The facility also houses a HELL chromacon system built in West Germany that produces a high quality color image directly from an input product tape. This feature bypasses the traditional route from digital tape to film writer to photo negative to photo lab, saving considerable time and (depending on the cost of the system and operating expenses) money. The image processing facility is considered to be state of the art and with the cooperation of ERSDAC stands to make significant contributions to remote sensing technology.

Research Activities. Like the other centers visited, research interests at JGI are shifting from the processing of Landsat, SPOT, and other "conventional" data sets to the anticipation of future systems that are expected to provide much higher quality data to build on the present technology. A first step in this effort is the participation in another JERS-1 simulator study, here in cooperation with several U.S. oil companies under the direction of the Geosat Committee, an organization that serves as the focal point for cooperative remote sensing studies. Unlike the ERSDAC study, which involved digital image manipulation to simulate stereo images, JGI is part of a team that is combining various data sets, including airborne scanners specifically flown for the purpose, to map test sites in the western United States (Ref 7). These data sets will be combined and evaluated for their effectiveness in regional mapping and for the discrimination of surface materials. JGI maintains their own field spectroradiometer to take in-situ measurements of rock reflectance to calibrate both lab and field spectra for comparison to the results of the study.

Other interests lie in probing additional bands within the near to intermediate IR spectrum, channels which should improve the ability to map subtle variations in surface materials and potentially detect geochemical alteration caused by mineral or petroleum deposits.

Of the groups visited, JGI is the most results oriented, draws on a large experience base, and has access to governmental technology through ERSDAC.

SUMMARY COMMENTS

These observations are based on limited visits to one administrative office (NASDA) and three working remote sensing research centers. This report represents my candid impressions of the capabilities of these groups that are colored by my own experience in the field. Each organization was extremely gracious and accommodating and demonstrated a sincere desire to share their goals and challenges with an outsider. I appreciated their willingness to discuss their goals, successes, and challenges.

I defend the selection of organizations on the basis that earth resources applications have typically driven remote sensing funding and, historically with them, the greatest advances in the technology.

With this review as a base, I suggest other centers of remote sensing activity in Japan should be visited, perhaps by someone with a strong background in the more specific aspects of remote sensing (possibly oceanography or naval operations), to more clearly define research directions of specific interest to ONR. I sense a strong interest in cooperating with the West and feel the opportunity is present for very worthwhile joint studies.

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MEDICAL RESEARCH IN CHINA

Jeannine A. Majde

A number of hospitals and universities were visited in the People's Republic of China to assess the general status of medical research and to seek any novel approaches used in traditional Chinese medicine for wound dressings.

BACKGROUND

China, because of its political and economic history combined with its tremendous intellectual resources, represents a unique scientific entity in the modern world. From a medical perspective, its research activities are shaped by the dominant force of infectious diseases now virtually unknown in the West. While introduction of some very basic public health measures (such as boiling drinking water) in the last 20 years has nearly doubled the life span of the Chinese people (from approximately 40 to 65 years), sanitation is still conspicuously lacking. For instance, tuberculosis is still spread by public spitting, a habit that is dying slowly. Primitive plumbing and personal hygiene habits certainly contribute to the spread of serious enteric diseases such as infant diarrheas and hepatitis A. Economic resources severely limit the technological approaches that can be used to deal with the public health needs of 1.1 billion people, most of whom have no access to a physician other than by a long bicycle trip. These socio-economic factors drive medical research in China, as will be apparent in the narrative to follow.

INTRODUCTION

This trip was conducted in association with a Delegation on Bioprosthetics organized by the Citizen's Ambassador Program of People to People International, Spokane, WA. This nonprofit organization arranges professional delegations in all subject areas initiated by suitably qualified persons (in this case, Prof. Marcel Nimni of the University of Southern California, a collagen biochemist). Expenses are paid by the delegates, and local support, such as translators and guides, is provided by the host organization (in this case, the Chinese Medical Association). The program is well run and I can recommend it strongly to scientists with a special interest in a scientific area based in a country such as China that is very difficult to access on an individual basis.

The Bioprosthetics Delegation visited the following universities and hospitals in Beijing, Chengdu, and Shanghai to assess the general status of medical research and to seek any novel approaches used in traditional Chinese medicine for wound dressings:

Beijing

- Tsinghua University
    - Laboratory of Biomechanics (Prof. Zhang Jichuan, director; Prof. Shen Zi-Wei, vice director)
    - Department of Biology
- The People's Liberation Army General Hospital Institute of Basic Medical Science Research
    - Basic Medicine Institute of Military Postgraduate Medical School (Prof. Zhang Zun-Yi)
    - Trace Element Research Laboratory (Prof. Zhao Lin, chief)
    - Sun Yan-Qun, orthopedic surgeon

Chengdu

- Chengdu University of Science and Technology Bioengineering Institute (Prof. Wang Jian-Hua, university president; Prof. Kang Zhen-Huang, Biomechanics Department; Dr. Tang Xudong, director, Office of International Programs; Prof. Yue Yi-Lun, director, Biomaterials Research Laboratory)
- West China University of Medical Sciences (Prof. Yu Baoliang, director)

Shanghai

- Ren-Ji Hospital, Shanghai Second Medical University (Prof. Li Xue-Min, director; Prof. Wang Yi-Shan, director, First Division of Cardiovascular Disease; Prof. Zhu Hong-Sheng, chief, Department of Cardiothoracic Surgery; Prof. Chen, Department of Microbiology)

DISCUSSION

At Tsinghua University (the most prestigious university in China) discussions focused on activities in the Laboratory of Biomechanics, which is interested in fluid mechanics in the heart as well as development of prosthetic limbs driven by myogenic signals. The Biology Department is only 4 years old but is flourishing with the aid of U.S.-trained scientists and a substantial equipment grant from the government--there I talked with scientists working on basic membrane biophysics in frog cells, plant biotechnology through electrofusion, liposome delivery of cancer chemotherapeutics, and basic panda biology.

At the Military Hospital I talked with Prof. Zhao in the Trace Element Laboratory regarding micronutrient studies in cancer epidemiology; he has shown that there is an association of low silicon with esophageal cancer and is interested in low zinc and high copper in cancer induction. The Clinical Immunology Laboratory is working on the role of fibronectin in breast cancer, a new antigen in tuberculosis, serum complement in kidney transplantation, and antigens associated with rheumatoid arthritis. Delegates also visited the traditional Chinese medicine wing of the hospital, which was using acupuncture (including taped seeds and electrostimulation needles as well as traditional needles to achieve pressure on the appropriate "pulses"), moxibustion (burning of a special herb on the afflicted area or related "pulse"), and herbal therapy to treat a wide variety of disorders unresponsive to Western approaches. (It should be noted that traditional Chinese medicine is used similarly in Japan when Western medicine fails. While the Japanese are actively seeking the scientific basis for the activity of traditional Chinese herbs, I could find no evidence of such research in China.)

The Chengdu University Bioengineering Laboratory is a strong force in development of biological heart valves made from yak pericardium, a tissue selected because the yak is slaughtered under clean conditions for Islamic citizens, allowing sterile harvest of tissue. Heart valve replacement is a frequent form of cardiac surgery in China due to the high incidence of rheumatic heart disease (0.8 percent of the population) resulting from frequent streptococcal infections. Because mechanical valves preferred in the West for young patients require long-term and often inaccessible medical follow-up to maintain anticoagulation, biological valves are used instead. These valves calcify rapidly in young individuals and must be replaced every 5 to 10 years, a painful and risky operation. Methods under investigation in the United States to prevent calcification of the collagen were actively discussed here and in Shanghai. To reduce the need for valve replacement surgery, efforts are now being made to control streptococcal infections in the countryside by appropriate diagnosis and treatment with penicillin--the method used in the West that has virtually eliminated rheumatic fever. Other topics discussed included work on biomechanics of blood flow and burn dressings composed of keratinocytes cultured on a matrix of cellophane. In the context of the latter, a U.S. delegate, Dr. Steven Boyce of the University of Cincinnati Medical Center, discussed his work on growing synthetic skin (also cultured keratinocytes) on a collagen matrix which offers several advantages over cellophane.

A visit was also made to the Computer Science Laboratory, which is engaged in a project to facilitate translation of Chinese characters and also trains students in computer programming.

At Ren-Ji Hospital in Shanghai we discussed cardiovascular surgery at length. This hospital is the second oldest in China and resides in an extremely congested part of this very congested city--while it has only 630 beds, it handles 3,500 to 5,000 patients per day and trains 300 medical students. It conducted the first open heart surgery in China in 1957 after acquiring a heart lung machine. Prof. Wang is a champion of the use of acupuncture anesthesia for open heart surgery, which he feels assists in the recovery of the patients by freeing them of the complications of anesthetics and by reducing arrhythmias. He illustrated his discussion with slides of a young boy undergoing such surgery who displayed no obvious signs of pain. Prof. Wang has operated on 260 cases using acupuncture but restricts them to short, simple cases where the patient is in a "stable psychiatric state." We also discussed some of the problems associated with organ transplantation and the blood supply in China. Heart transplants are severely limited by shortage of organs because the Chinese people refuse to remove vital organs from the dead on religious grounds; additionally, there is no money for cyclosporin, the immunosuppressant drug used in the West to overcome rejection, which costs $60,000 per year per patient. Most blood that is transfused is stored frozen (a technology developed by the U.S. Navy) to deal with logistics problems--this practice may also inadvertently help to reduce hepatitis (hepatitis B is endemic in China) in recipients due to mechanical removal of the virus by washing.

At the Shanghai Second Medical University Department of Microbiology a fellow delegate from Brown University, Dr. Thomas Kresina, talked about his work on anti-idiotype vaccines in schistosomiasis, a common but diminishing (due to drastic control of the snail vector with molluscicides ending in 1985) parasitic infection in China. This group is investigating the use of an antibody test to detect the presence of residual schistosomes in treated patients, the development of a DNA probe for diagnosing toxoplasmosis, another common parasite, and overwintering of mosquitoes in malarious areas.

CONCLUDING REMARKS

In China, training physicians as well as other scientists is constrained by university space--only 400,000 students can be trained per year in all fields of study, although there are over a million applicants. I was extremely impressed with those that manage to float to the top and achieve university positions (at salaries less than one-tenth of that of a cab driver in Beijing)--never have I experienced such intellectual curiosity and drive. While I encountered no scientific achievements of outstanding merit (and in fact learned the most science from my fellow delegates), I left with the feeling that the concept of a "sleeping giant" definitely describes Chinese science if it should be allowed by political and economic forces to waken. The Chinese have achieved a respectable amount of rigorous science with almost nothing--they have exploited the foreign (mostly U.S.) training they have been allowed to have to the limits. The current political situation will undoubtedly have a negative impact on the university system and is likely to result in closing off training opportunities at home and abroad. This can only be considered a loss of intellectual resources for the world.

Dr. Jeannine A. Majde is the Program Manager for Systems Biology at the Office of Naval Research (ONR) in Arlington, VA, where she currently serves as Scientific Officer for immunology, cell biology, neurophysiology, and medical materials. Her formal training is in virology and immunopathology and she currently conducts research in viral toxicity mechanisms and physiological regulation of macrophage-virus interactions in defined culture systems. She has developed ONR programs in immunopharmacology, physiological regulation of the immune system, and cell biology of trauma and is engaged in managing the exploratory development and industrial transition of two medical materials (a blood substitute called liposome-encapsulated hemoglobin and a therapeutic for ischemia called oligo-prostaglandin B). In her 16-year career with ONR Dr. Majde has received numerous performance awards and the Navy Meritorious Civilian Service Award for her contributions to the Navy Blood Program.

SUPERCONDUCTING ELECTRONIC AND FILM TECHNOLOGY IN JAPAN

Harold Weinstock and Robert H. Hammond

In this article highlights of the Second Workshop on High-Temperature Superconducting Electron Devices and the International Superconductivity Electronics Conference are presented. In addition, Japanese progress and plans for ongoing programs in conventional low-temperature (niobium and niobium nitride) superconductive electronics as well as in electronic elements and devices using the newer high-temperature (ceramic) superconductors are assessed by site visits to three government-supported laboratories and three major industrial laboratories.

INTRODUCTION

This is a report on our observations of Japanese research on superconductive electronics and the underlying thin film technology. In June 1989 we attended the Second Workshop on High-Temperature Superconducting Electron Devices and the International Superconductivity Electronics Conference (ISEC '89). Additionally we visited the new Superconductivity Research Laboratory of the International Superconductivity Technology Center (ISTEC), the Electrotechnical Laboratory (ETL), and the National Research Institute for Metals (NRIM), all government-supported laboratories with strong industrial coupling, and three major industrial laboratories: Hitachi, Fujitsu, and NEC.

Our goal was to assess Japanese progress and plans for ongoing programs in conventional low-temperature (niobium and niobium nitride) superconductive (LTS) electronics as well as in electronic elements and devices using the newer high-temperature oxide superconductors (HTS). With the exception of the ISTEC laboratory, with its mission tied exclusively to the fundamentals of HTS materials, all labs visited had programs in both LTS and HTS. This is not surprising because the excitement over HTS is perhaps greater in Japan than anywhere else. The three industrial labs visited and ETL are all part of the Ministry of International Trade and Industry (MITI) 10-year Josephson digital logic program now nearing its end, and NRIM has been involved in the construction of conventional LTS magnets for many years. In every one of these laboratories the major thrust is in the direction of HTS materials and devices. Although it is far too early to speculate on future products, the Japanese scientists we met were resolute in their belief that after 10 to 20 years of research and development HTS technologies will be a major contributor to their country's economic well being.

Additional evidence for this view is derived by examining the programs of the two meetings we attended. At the first International Superconductivity Electronics Conference (ISEC '87) held at the end of August 1987, almost all presentations related to LTS electronics, with only a few "late news" papers presented on early materials work on HTS. At ISEC '89 the majority of presentations related to HTS, although the focus was almost entirely on how to make good-quality films and tunnel junctions. Since there are still major problems in both these arenas, HTS devices and circuits were not discussed to any great degree. Ironically, the same can be stated with regard to the Second Workshop on High-Temperature Superconducting Electron Devices; despite its title, the presentations focused on film growth and attempts to make tunnel junctions, not on devices.

The reader can find an excellent introduction to HTS film technology in general, and to the status of this technology in Japan specifically, by referring to the article by Osofsky, Broussard, and Callen in the *Scientific Information Bulletin.** We add below some additional comments to update the technology as needed to discuss our observations.

NEW TECHNIQUES FOR THE GROWTH OF SUPERCONDUCTING THIN FILMS

In the article referred to above, two techniques of thin film synthesis were discussed: evaporation and sputtering. At that time these approaches required subsequent heat treatment to react and order the material--the so-called postannealing step. Significant success is now being reported using the so-called in-situ growth (in Japan this is often referred to as "as made") methods. The film quality, at least for YBCO, is "better," i.e., there is less substrate diffusion because a lower growth temperature is possible. This results in better epitaxy, thus higher critical currents, sharper and higher T_c, and lower rf surface losses. It appears that the first in-situ growth was achieved by Dr. K. Wasa's group at Matsushita Electric Industrial Co., Ltd., Osaka, using single-target (a compensated compound of YBCO) rf magnetron reactive sputtering. The majority of the Japanese workers use this method, which has the problem that negative oxygen atoms are accelerated away from the target along the axis and re-sputter material from the substrate. To compensate, the composition of the target is chosen empirically to give the correct stoichiometric composition, which unfortunately is over a small area of the substrate. A successful solution to this problem has been to place the substrate off-axis, away from the direction of the oxygen atoms. The idea for this, in the case of the Stanford work (which has influenced many workers throughout the United States), came originally from Professor H. Koinuma now at the Tokyo Institute of Technology. Dr. Rossnagel at IBM independently found this method to be successful and did much to explain the negative oxygen processes.

YBCO films of very high quality are now being made using this technique in the United States. Equally high quality films of YBCO are being made by another technique, also not mentioned in the above article.

*M. Osofsky, P.R. Broussard, and E. Callen, "High temperature superconducting thin films in Japan," *Scientific Information Bulletin* 13(4), 1-23 (1988).

This is pulsed laser ablation of a composite compound target. The early leaders in this field have been the Rutgers/Bellcore group in the United States and Siemens in West Germany. Finally, other methods are becoming successful after a long period of effort and could become the most promising for large scale production. These are chemical vapor deposition (CVD) and metal organic chemical vapor deposition (MOCVD). Some of the recent promising results are coming from Japan.

SECOND WORKSHOP ON HIGH-TEMPERATURE SUPERCONDUCTING ELECTRON DEVICES

This workshop was held under the auspices of the Japanese Research and Development Association for Future Electron Devices in Shikabe, a small fishing village on the northern island of Hokkaido, on 7-9 June 1989. Although co-sponsored by a number of Japanese groups and organized exclusively by Japanese scientists, the workshop was advertised internationally; 30 foreign scientists, about half from the United States, many of whom were invited speakers, attended. These foreign attendees were joined by 140 Japanese scientists.

The sessions were organized along four major themes: thin film fabrication, film characterization, current status of devices, and future device prospects. However, in light of the infancy of HTS materials scienceand technology, most of the presentations were devoted to the first two topics. Emphasis was about equally divided between the "older" "123" materials, primarily yttrium barium copper oxide, and the newer bismuth- and thallium-based HTS materials, primarily bismuth strontium calcium copper oxide.

In reporting fabrication, more than half of the films were made by single-target magnetron sputtering, while some films were made via multitarget sputtering. There were only a limited number of presentations on electron-beam and laser deposition. However, there were a few papers on chemical vapor deposition, which in a relatively short time has managed to produce HTS films of a quality approaching that of the best sputtered films, i.e., a group from Oki Electric reported that for a 3,500-Å film on (100) $SrTiO_3$ they achieved a $T_c(R=0)$ of 88 K and $J_c = 5 \times 10^5$ A/cm^2 at 77 K. For comparison the "best" films made using the off-axis sputtering and laser ablation techniques have $T_c(R=0)$ of 90 K and $J_c = 5 \times 10^6$ A/cm^2 at 77 K.

In Japan, there appears to be less interest than in the United States in passive, high-frequency applications; thus high-frequency surface loss measurements are generally not made, and there is little motivation to make very high quality films (with high T_c, high J_c, low surface loss at high frequency). In general, there is less coupling of materials work and the physics in the industrial basic research in Japan, as compared to elsewhere. This may explain why the quality of Japanese films is often not as good as elsewhere. "In situ" (in the United States, "as made" in Japan) high quality films are now more common. Indeed, as mentioned above, the first to make such a film was Wasa's group at Matsushita, and Professor Bando at Kyoto University has been a leader in such high quality films, using thermal coevaporated metal sources.

INTERNATIONAL SUPERCONDUCTIVITY ELECTRONICS CONFERENCE (ISEC '89)

This conference, held 12-13 June 1989 in Tokyo, is the second in a series that began as a 2-day satellite meeting (to LT-18) held in late August 1987 (also in Tokyo). While both conferences were organized by the Japanese hosts, the IEEE Electron Devices Society, the Japan Society of Applied Physics, and the Cryogenic Society of Japan were cosponsors. Financial subsidies were obtained from 21 Japanese industrial companies. In an effort to have this meeting take on a more global character, the Japanese organizers initiated a move to hold the next meeting in another country. Accordingly, it was announced that ISEC '91 will take place at the University of Strathclyde, Scotland (hosted by Professor Gordon Donaldson), in June 1991; it will be coordinated with IC SQUID '91, which will be held in Berlin at about the same time.

Once again, attendance and participation at the meeting were dominated by scientists from the host country. There were 204 attendees from Japan and 59 from other countries. Of this latter number, the United States made the largest contribution with 21, followed by 10 from the U.S.S.R., 8 from China, 6 from the Federal Republic of Germany, and 3 or less each from the United Kingdom, Italy, France, Korea, Australia, Denmark, India, and Taiwan.

Breaking the presentations down into three categories, HTS films, HTS devices, and LTS devices, we note 46 in the first category, 29 in the second, and 53 in the third. Many of the HTS papers were similar or identical to those presented a few days before in Shikabe. Also, many papers masquerading as related to HTS devices were primarily attempts to deposit HTS films onto a buffer layer in contact with silicon, with no attempt to fabricate a hybrid superconductor/semiconductor device in the foreseeable future. Nevertheless, there is an abiding faith among many Japanese scientists that such devices will eventually be made and find a wide market for their adoption.

A highlight of the ISEC '89 meeting was a review presentation by Professor K.K. Likharev of Moscow State University titled "Progress and Prospects of the Superconductor Electronics." In the first part of his talk he dealt with LTS--mostly niobium based--electronics, covering resonators, transmission lines, switches, bolometers, SQUIDs, analog devices, digital circuits, and a/d (as well as d/a) converters.

Under the category of digital circuits, although he acknowledged the considerable success of the Japanese (specifically Fujitsu, Hitachi, NEC, and ETL) in designing, fabricating, and testing logic and memory circuits, he presented a strong endorsement for a relatively new concept known as rapid single-flux-quantum (RSFQ) logic, which Likharev originally had proposed in 1985. A conventional Josephson logic bit uses the zero voltage state as a "0" and the (latched) voltage state as a "1." In RSFQ logic the binary unit is an SFQ pulse rather than a dc voltage. The zero condition is encoded by the absence of such a pulse in a given time interval.

The great virtue of RSFQ logic is that the power consumption can be a thousand times less than for latching Josephson logic (which itself is about a thousand times less dissipative than semiconductor logic before considering refrigeration requirements). It also is at least 30 times faster than similar circuits using latching logic. Since 1986 Likharev and his collaborators have designed, fabricated (using 10- or 5-μm all-Nb technology), and tested RSFQ circuits with clock frequencies up to 100 GHz. With reduction to 1-μm design rules he expressed belief that the clock frequency could be raised to 300 GHz.

It should be noted that there is a similar form of nonlatching Josephson logic being pursued in Japan that is based on the innovative work of Professor E. Goto of the University of Tokyo. The Japanese Research and Development Corporation, an arm of MITI, is supporting a 5-year program, known as the ERATO Project, which is aimed at developing Josephson logic and memory based upon Goto's concepts. Scheduled to conclude by the end of 1991, the program is housed in space rented at the Hitachi Central Research Laboratory and is staffed by not only Japanese scientists but some from other countries.

One reason there is so much interest in nonlatching logic is that if a manufacturable HTS Josephson technology is developed, a latching logic operating near liquid nitrogen temperature ($\leq$77 K) would dissipate almost as much power as semiconducting gates. This would not be so for the nonlatching logic.

Likharev, in considering HTS electronics, started with a brief review of potential applications: emf shielding, bolometers, resonators, transmission lines, and interconnects. He pointed out that superconducting shielding would be particularly valuable at relatively low frequencies (below about 1 kHz) where normal-metal shields would be too thick.

The major thrust of his HTS electronics discussion revolved about three possible scenarios for the development of HTS Josephson junction electronics:

(1) Very unfavorable, i.e., all attempts to fabricate reproducible junctions fail, and the only junctions that can be made use grain boundaries.

(2) Most probable, i.e., within 2 or 3 years a technology is established in which junctions can be made reproducibly with similar physical characteristics.

(3) Extremely favorable, i.e., a technological miracle provides reproducible BCS-scaled junctions.

Under scenario (1) only SQUID magnetometry will be influenced. Scenario (2) would lead to manufacturable samplers, receivers, a/d converters, and digital devices. While scenario (3) would appear initially to be most desirable, Likharev observed that for many devices it provides no great advantage over scenario (2).

Perhaps the most impressive technological achievement reported at the meeting involved the presentation by Siemens scientists (G. Daalmans et al.) on a 31-channel dc SQUID gradiometer array system for biomagnetic diagnosis. The system described represents a significant escalation (from a current high of 14 in operating commercial SQUID arrays) in the number of SQUID-based magnetic gradiometers used to map human biomagnetic field contours. With such a large number of individual sensing units within a single instrument package, the authors claim that only a single positioning of the dewar containing the sensor array is required to obtain a complete magnetoencephalographic (MEG) mapping.

The SQUID array consists of four chips of 10 dc SQUIDs, each deposited on silicon wafers using an eight-level process with minimum widths of 2 μm. Each chip is 1 cm on a side, while each SQUID, apart from connections to bond pads, occupies an area of 800 by 800 μm. Using a moderately shielded room in an urban environment, overall system performance was characterized by a resolution of better than 20 fT/$Hz^{1/2}$ in the frequency range 5 Hz to 1 kHz. This is comparable to values in smaller commercial arrays that do not use all-thin-film SQUID technology.

The SQUID sensors are coupled to 31 conventional superconducting first-order gradiometer coils, each with a 3-cm diameter and a 7-cm baseline. These fit over a 20-cm diameter into the tail section of a flat-bottomed (HOXAN Corp.) dewar. No doubt this flat-bottomed cylindrical geometry makes construction simpler, but it does mean that coils on the periphery are quite far from the source within the brain, and the 2.5-cm spacing between the bottom of the coils and the outside of the dewar is already a little greater than the separation for existing commercial systems. Nevertheless, the papers presented showed MEG data that were comparable to anything obtainable with conventional smaller array systems. One special feature of the Siemens prototype unit (it is not yet available for purchase) is that the localization of the apparent dipole source producing the MEG contour is superimposed upon a magnetic resonance imaging (MRI) photograph of the same subject's brain. The combination of these two diagnostic technologies, one (MEG) relating to brain function and the other (MRI) relating to brain structure, represents a powerful new tool for neurological science. Additionally, the 31-channel dc SQUID array should prove quite useful in diagnosing cardiographic dysfunction.

ISTEC

A previous issue of the *Scientific Information Bulletin** featured a report based on a fall 1988 visit with Professor Shoji Tanaka, director of ISTEC. The report by Donald Liebenberg provided details of ISTEC's support from both industry and government and of its organizational structure. At that time, however, the primary ISTEC laboratory facility had not yet been completed and occupied. Such was not the case on our 6 June 1989 visit.

Contrary to the belief that ISTEC's Superconductivity Research Laboratory (SRL) was housed in a renovated building donated by the Tokyo Gas Co., we found a modern building that had been constructed specifically to house SRL. Occupying over 36,000 square meters over two levels, the building was built from the ground up in a period of 6 months and already had been occupied for alike period of time. SRL is staffed with 2 researchers from each of 46 contributing Japanese industrial organizations and has an additional administrative staff of 18. Professor Tanaka indicated that an adjacent three-story building is being planned to avoid overcrowding.

It appeared that the last major pieces of equipment were expected imminently or were in the process of being installed. From what equipment we did see, e.g., a top-of-the-line JEOL electron microscope, it was clear that SRL will be one of the best-equipped labs of its type in the world. In addition to the research groups (or divisions) reported in the previously mentioned ISTEC article, a seventh division (in reality Division 6) for establishing a comprehensive superconductivity data base is being initiated. Also, the division for research in

* D. Liebenberg, "A series of site visits on superconductivity," *Scientific Information Bulletin* 14(2), 153-167 (1989).

organic superconductivity has been formed, with Professor Tanaka as the leader of three researchers and with close ties to work in this field at the University of Tokyo. It should be reiterated that the work on bulk ceramic superconductivity for high current wires is being carried out by SRL's Nagoya Division located within the confines of the Japan Fine Ceramics Center.

HIGHLIGHTS OF CONFERENCES AND LABORATORY VISITS

In the following, we will discuss certain topics that attracted our attention out of the many presented at both conferences and during our visits to the laboratories.

There were a number of reports concerning approaches to atomic engineering--the sequential deposition of the elements to synthesize a desired structure that may not be able to form in thermodynamic equilibrium. By choosing the growth temperature appropriately it is possible to form a metastable, or stable at the temperature of deposition, structure that is not stable at the usual temperature of bulk synthesis. Because the high temperature superconducting copper oxides are generally layered structures, they become natural materials to form by sequential elemental layering. The Japanese are leaders in terms of active groups taking this approach. At both conferences Dr. Setsune, working in Dr. Wasa's group at Matsushita, described their attempts to make $Bi_2Sr_2Ca_xCu_{1+x}O_y$ (BSCCO), where x ranged from 1 to 4, with the T_c in the bulk form of these structures ranging from 80 to 110 K. Their results were similar to those reported by other Japanese researchers on the same system (using variations in the method of deposition). X-ray diffraction indicated that the correct structures were being formed, but the T_cs were low until a high-temperature postanneal with oxygen was done.

Other researchers in Japan doing similar research include Fujita at NEC and Ogawa and coworkers at the National Research Institute for Metals.

For many applications a crossover of two YBCO films is necessary. One example is in the fabrication of the coil for a SQUID. The first reported crossover anywhere was given by Furuyama and Iguchi (University of Tsukuba). The YBCO films were separated by 300 Å of MgO, grown at 600 °C, and both YBCO films had $T_c(O) > 75$ K. At a substrate temperature of 650 °C the lower film deteriorated during deposition of the MgO-YBCO top layers. The structures are epitaxial but show roughness, and thus may have pinholes or shorts for thinner dielectric thickness.

Attempts to make devices using the decrease in T_c due to oxygen depletion as a control channel in a FET-type configuration were reported. Results were considered promising, but it is not clear if the results observed are due to the effects as claimed. However, the configurations studied are interesting.

Deposition of BSCCO on Si by halide CVD using a double buffer layer of CVD grown $MgO\text{-}Al_2O_3$ (spinel)/MgO was reported by the Fujitsu group. The $T_c(O) =$ 77 K is low but is due to the CVD process itself, as this is the value of $T_c(O)$ found when BSCCO is deposited directly on MgO.

Weak links made by a variety of processes were reported. Two of these were by the "poisoning" method:

(1) Grow YBCO over narrow SiO_2 strip, then cover with Ag (Hayakawa, Nagoya University)

(2) Selectively diffuse Ag and Au into a narrow region (Kuriki, Hokkaido University)

Setsune (Matsushita) reported on films of the electron-doped superconductor Nd-Ce-Cu-O [$T_c(O)$ = 22 K]. This material is interesting because in order to get metallic conductivity and superconductivity, it is necessary to anneal in vacuum at 800 to 900 °C so that oxygen is removed--just the opposite of what one does for YBCO. In the latter case there is a problem at the surface in vacuum because it is suspected that the oxygen depletion there is harmful to the performance of tunnel junctions. Thus, the new material may prove to have an inherent advantage in this aspect.

Investigators at a number of companies are exploring the use of techniques for the new superconductors that are now used for semiconductor circuit microfabrication. These include focused ion beam (FIB) for patterning without masks, patterning by ion implant, and the use of reactive ion beam etching (RIBE) using Cl_2 and SF_6. Both show enhanced etch rates over Ar ions under certain conditions when used on YBCO.

Although there have not been any major new HTS developments recently in Japan (as well as elsewhere in the world), there is interesting technology being developed. Not all approaches are successful at this time, but steady progress is being made in the effort to "tame" these difficult oxides.

Harold Weinstock has been a program manager since 1986 at the Air Force Office of Scientific Research, where he funds basic research on ceramic superconducting materials and on electronics encompassing both LTS and HTS superconductors. He is the coordinator of all research and development activity on superconductivity within the Air Force and serves as a principal advisor to the Strategic Defense Initiative Office on this same topic. Dr. Weinstock is a former professor of physics at the Illinois Institute of Technology, where one of his principal research activities involved transport measurements and radiation damage studies of superconductors. More recently, he has applied superconducting (SQUID) magnetometry to studies of basic magnetism, neuromagnetism, and nondestructive evaluation (NDE). He still is engaged actively in SQUID applications to NDE--a field he helped pioneer--through a collaborative effort with scientists at the Naval Research Laboratory (NRL). Dr. Weinstock received a B.A. in physics from Temple University in 1956 and a Ph.D. in experimental physics from Cornell University in 1962. He has authored about 100 publications and is a Fellow of the American Physical Society. Dr. Weinstock is co-editor, with Dr. Martin Nisenoff of NRL, of a newly published book titled *Superconducting Electronics*, which is based upon a recent NATO Advanced Study Institute.

Robert H. Hammond is a senior research associate at the W.W. Hansen Physics Laboratory, Stanford University, where he has been since 1971. His major research activity is the synthesis and study of thin films of metal alloys and compounds (the phase stability and metastability of alloys and compounds, and the mechanisms of superconductivity in crystalline and amorphous materials). He holds B.S., M.A., and Ph.D. degrees in physics from the University of California, Berkeley. From 1960-68 Dr. Hammond worked at General Atomic to develop techniques for forming thin films of Nb_3Sn using multiple controlled sources. At the Lawrence Berkeley Laboratory, University of California (1968-71) he synthesized new superconductors (V_3Al and Nb_3Si) and surveyed the superconducting behavior of the transition metal series in the thin film amorphous state. He has used these techniques at Stanford to study the superconducting tunneling and the high field behavior of superconducting thin film metals. Since 1986 he has concentrated on the copper oxide high T_c superconducting thin films. He has about 80 publications in low temperature and 8 in high temperature superconducting thin films.

INTERNATIONAL SYMPOSIUM ON COMPUTATIONAL FLUID DYNAMICS-NAGOYA

Hideo Yoshihara

Some select papers presented at the International Symposium on Computational Fluid Dynamics (ISCFD) are briefly reviewed. The technical caliber of the papers was on the level of the American Institute for Aeronautics and Astronautics Computational Fluid Dynamics presentations.

INTRODUCTION

The Nagoya meeting was the third in the series, with the first held in Tokyo in 1985 and the second in Sydney in 1987. Co-chairmen of the meeting were Professor M. Yasuhara (Aeronautics Department, Nagoya University) and Professor H. Daiguji (Mechanical Engineering Department, Tohoku University). The symposium was sponsored by the Japan Society of Computational Fluid Dynamics (JSCFD), which is chaired by Professor K. Oshima of the Institute for Space and Astronautical Sciences (ISAS) with financial support from the Ministry of Education, Science, and Culture and major industrial companies. JSCFD is the dominant computational fluid dynamics (CFD) organization in Japan and organizes most of the CFD workshops and conferences in Japan, both national and international. The International Advisory Committee for ISCFD included the following U.S. members: Dr. Douglas Dwoyer (NASA-Langley), Victor Peterson (NASA-Ames), Professor R. MacCormack (Stanford University), and Professor Thomas Taylor. All presentations were in English.

There was a special effort spearheaded by Professor Oshima to promote attendance from the U.S.S.R. and China. Accordingly, 20 speakers from the U.S.S.R. and 7 from China were invited with all expenses paid by the symposium. Among the invitees from the U.S.S.R. were Academician O.N. Belotserkovski (Institute of Computer Aided Design, Moscow), Professor V.P. Korobeinikov (Institute of Applied Mathematics, Vladivostok), Professor V.V. Rusanov (Keldish Institute of Applied Mathematics, Moscow), and Professor Y.I. Shokin (Computing Center, Academy of Science, Krasnoyarsk). Among the invitees from China were Professor F.G. Zhuang from the Chinese Aerodynamics Research Society, Beijing, who received his graduate education at the California Institute of Technology, and other invitees from the Academia Sinica-Beijing, Beijing University, Tsinghua University, and the Beijing Institute of Aerodynamics.

There was an unfortunate last-minute cancellation of 11 previously approved NASA papers including a NASA-sponsored paper by Professor G. Bird of Sydney University.

One of the cancelled papers was a keynote address by Dr. J. Steger, who is highly respected in Japan. Needless to say, there was great concern and consternation among the symposium management.

During four concurrent formal sessions and two poster sessions 233 papers were presented. There were 190 attendees from Japan and 80 from outside Japan, with the following countries represented: the U.S.S.R. (37), the United States (16), China (8), France (8), FRG (6), Italy (6), Australia (4), plus other attendees from Canada, India, Sweden, the United Kingdom, Bulgaria, Israel, and Turkey. The policy of the program committee apparently was to accept all reasonable papers, and unfortunately, as a result, many excellent papers were relegated to the poster sessions. The following session titles reflect the subject matter covered in the symposium: numerical methods, turbulence, reacting flows, incompressible Navier/Stokes, rarefied gas flows, free surface flows, Euler equations, high speed flows, finite element methods, shock waves, numerical simulation, boundary element methods, boundary conditions, and vortex flow and applications.

COMMENTS ON SELECTED PAPERS

One of the five keynote papers receiving wide interest was by Professor A. Jameson of Princeton University titled "Computational Aerodynamics and Aerodynamic Design," in which he reviewed his recent activities at Princeton University. (This paper did not appear in the Proceedings, but the contents were essentially covered in a 28 July 1989 issue of *Science Magazine*.) Three items covered by Dr. Jameson were of significance. First was the application of an unstructured tetrahedron grid to the MD-11 transport configuration. Of importance here was the ability to generate a high quality grid over a complex configuration with a production code with only a week's effort. In contrast, it would take an expert at least several months' effort to generate structured grids with many blocks. The second contribution was the use of a high-order Kutta-Runge explicit method with implicit residual averaging and multigrid. A high quality Navier/Stokes solution for an airfoil and an Euler solution over the MD-11 configuration were achieved with greatly reduced computing time relative to widely used implicit methods. The third contribution was the use of a new turbulence model, the Renormalization Group Theory (RNG) model by Orszag/Yakhout, for transonic airfoils where an algebraic version gave excellent agreement with experiments. In cases with shock-induced separation, however, the test/theory agreement in the post-shock region was less satisfactory. Most probably a prior-history RNG model is needed for these cases. Other papers on unstructured grids were presented by Professor K. Nakahashi of the Osaka Prefectural University and Dr. J. Periaux of the Dassault Company, an early user of the unstructured grid.

Professor N. Satofuka of the Kyoto Institute of Technology over the past several years has been calculating transonic flows over airfoils and wings using essentially the same procedure as Professor Jameson. That is, Professor Satofuka used the Rational Kutta-Runge method with residual averaging and multigrid methods. In addition, at the symposium he showed that such explicit codes could be efficiently parallelized by domain decomposition and demonstrated the parallelization procedure for airfoils on Titan and FPS parallel computers.

Another keynote paper was by Dr. P. Morice of ONERA titled "Some Recent Progress in CFD at ONERA." Of special interest was the variational technique for mesh optimization based on sound mathematics that insured a well-posed problem. This is in contrast to many earlier variational mesh optimization methods.

A third keynote address was by Professor Y. Miyake and Dr. T. Kajishima of Osaka University titled "A Discussion on Turbulent Flows in Pipes and Channels on the Basis of Large Scale LES." Readily available supercomputers have enabled them to compute channel flows at a Reynolds number (based on centerline velocity and channel width) of 4940 using 3.83×10^6 mesh points. Despite the title, the calculations were restricted to channel flows. The three cases considered were the steady channel flow, a channel flow rotating about an axis normal to the walls, and a steady channel flow with essentially streamwise sinusoidal area variation. Finite differences were used across the channel with standard periodic boundary conditions in the streamwise and spanwise directions. Smagorinsky subgrid viscosity was needed to maintain stability. The mesh, however, was sufficiently refined that the subgrid energy was negligible. The authors mentioned that their results closely matched experiments with respect to the mean distance between streaks, location of turbulent energy peaks, and several other significant statistical quantities. In the case of the rotating channel, the effect of the Coriolis force was correctly reproduced with Reynolds stress amplification on the pressure side and its suppression on the suction side. At a sufficiently large rotation rate a near-relaminarization was produced on the suction side, but this flow was distorted by the Smagorinsky subgrid viscosity, which could not be turned off conveniently. Of great interest was their assessment of several turbulence models using the "direct simulation" results. For the turbulence dissipation and other significant turbulence quantities there was a major deficiency near the walls for those models employing isotropy.

There were two other keynote addresses. Professor H. Oertel, formerly at DFVLR-Gottingen and now at the Technical University of Braunschweig, reviewed CFD activities in Germany and Dr. Y. Tago of Fujitsu Limited briefly reviewed the supercomputer history in Japan and gave samples of recent large scale non-CFD calculations.

ANNOTATED LISTING OF OTHER PRESENTATIONS

In brief, other notable presentations were as follows:

- H. Zhang and F. Zhuang, "NND Schemes and Its Applications to Numerical Simulation of Two and Three Dimensional Flows," China Aerodynamic Research and Development Center. NND is an acronym for "non-oscillatory, no free parameters, and dissipative schemes." The authors developed a scheme to prevent wiggles in capturing shocks requiring significantly less computing time than the usually used TVD-type schemes. They achieved this by tailoring the third order diffusion truncation error terms in the modified equation to enforce the entropy condition. They demonstrated the viability of their model for a wide variety of cases.

- S. Takanashi, "A Simple Algorithm for Structured Grid Generation With Application to Efficient Navier/Stokes Computations," National Aerospace Laboratory (Chofu City). An elliptic mesh generation method for Navier/Stokes calculations over complex configurations was developed using electrostatic theory to significantly reduce the computing time.

- T. Fujiwara and K.V. Reddy, "Propagation Mechanism of Detonation-Three Dimensional Phenomena," Nagoya University. This is one of several excellent papers presented by Professor Fujiwara and his colleagues. He is perhaps the leading researcher in Japan on high temperature gas dynamics. The problem solved was the three-dimensional perturbation of an axial symmetric oxy-hydrogen detonation flow in an annular cylindrical channel. The unsteady Euler equations were used together with a simplified H_2-O_2 chemistry. The complex shock configurations were captured cleanly, revealing hitherto unknown shocks.

- K. Nambu, "Monte Carlo Simulation of Various Kinetic Equations," Tohoku University. Monte Carlo methods treat rarefied gas flows mechanically, calculating the motion of a collection of molecules through a sequence of collisions. Professor Nambu's contribution was in establishing the connection of a Monte Carlo simulation with the stochastic representation of a given kinetic equation as the Boltzmann equation. Thus Bird's Monte Carlo method was shown to be the stochastic equivalent to Kac's kinetic equation for the multiparticle distribution function. Such correspondences strengthen the foundation of Monte Carlo methods, but developers of Monte Carlo methods probably see no need for such connections.

- N. Hirose, K. Asai, K. Ikawa, and R. Kawamura, "Computational and Experimental Analysis of Transonic Fanjet Engine Flow Field Using a 3-D Euler Code," National Aerospace Laboratory and Nihon University-Funabashi. Flow over an isolated fanjet engine was calculated assuming flux plate conditions in the engine interior. Two engines were considered, the turbo-powered simulator (TPS) and an actual engine. TPS is a model engine installed on wind tunnel models to simulate powered effects. It differs from an actual engine by having a cold core flow instead of a hot core flow and by a difference in the relative mass fluxes between the core and fan flows. The TPS results for the pressure distributions on the engine and cowl surfaces agreed well with experiments. There were differences in the surface pressures between the TPS and the actual engine, as must be expected, which were similar to the effect due to a change of angle of attack. Calculations were also carried out for the fan and core exhaust plumes. Clearly the inviscid approximation of the plumes will cease to be valid.

CONCLUDING OBSERVATIONS

The overall quality of the ISCFD papers was on a par with that of the Computational Fluid Dynamics meetings of the American Institute for Aeronautics and Astronautics. Oral presentations by the majority of Japanese speakers were, however, poor. The inability to speak English clearly is a factor in the lack of participation by Japanese attendees in the discussions.

There is no question that CFD progress in the U.S.S.R. and China has suffered significantly by the unavailability of supercomputers. On the other hand, the Soviet papers (and to a lesser extent the Chinese papers) at Nagoya showed strong theoretical capabilities that are their trademark. Here one is reminded that three of the powerful CFD concepts, approximate factorization, multigrid, and upwind schemes (TVD), are due to the Soviet scientists. It is only a matter of time before the CFD capabilities in the U.S.S.R. and China will be abreast of the United States, just as European capabilities have rapidly caught up with the United States during the past several years.

Undoubtedly the United States will continue to dominate CFD activities for many years to come simply by the overwhelming number of outstanding CFD researchers active there. The large CFD activity in the United States also parlays into the existence of a large, highly productive staff of algorithm and mesh generation specialists who are in short supply outside the United States. Because of the much smaller CFD community, the accessibility of supercomputers in Japan far exceeds that in the United States and Europe, and this will be an important factor in the future development of CFD in Japan.

Hideo Yoshihara arrived in Tokyo in April 1988 for a 2-year assignment as a liaison scientist for the Office of Naval Research. His assignment is to follow the progress of advanced supercomputers and to review and assess the viscous flow simulation research in the Far East. Dr. Yoshihara formerly was with the Boeing Company, where he was Engineering Manager for Applied Computational Aerodynamics. He was also an affiliate professor in the Department of Aeronautics and Astronautics of the University of Washington, an AIAA Fellow, and a former member of the Fluid Dynamics Panel of AGARD/NATO.

UNIVERSITY OF THE RYUKYUS

Earl Callen

The University of the Ryukyus, founded by the U.S. Civil Administration in 1950, is now a flourishing member of the Japanese national university system. It has engineering, medicine, law, and business schools and a college of science with the usual departments. Research tends to center on island concerns--coral reef geology, carbonate geochemistry, tropical vegetation, solar and wind energy, ocean science, typhoons, earthquakes, volcanoes. But there are active research efforts in mathematics, many-body and high energy physics, magnetic properties of rare earths, splat cooled iron ribbons, and shock wave compaction of metal powders, for example.

INTRODUCTION

In 1950 the U.S. Civil Administration established on Okinawa the first public institution for higher education in the Ryukyu archipelago (140 islands of which 47 are populated), the University of the Ryukyus. The school was erected in Naha on the ruins of the ancient stronghold of the Okinawan royalty, Shuri Castle, destroyed in World War II. The islands had long endured first Chinese and then joint Chinese and Japanese sovereignty, paying annual tribute to both powers since 1609 under the first Tokugawa shogunate, which closed Japan and the Okinawa islands to foreigners. American contact dates from 1853, when Commodore Mathew Perry on his way to Japan landed at Naha, introduced himself to the King of Okinawa, and prevailed upon the Japanese powers to allow coal bunkering by American vessels. With the ascendence of Japanese military might under the Meiji restoration, Japan rebuffed China, crushed Okinawan opposition in 1871, annexed the islands as a Japanese prefecture in 1879, and thereafter extracted a greatly increased tax-tribute. Almost one-fourth of the population, more than 200,000 Okinawan soldiers and civilians, gave their lives battling the American invasion in 1945.

From those terrible beginnings and from American post-war generosity evolved a friendship between Okinawa and the United States. Recognizing the need for a trained faculty and prepared student body, the U.S. Civil Administration, from the inception of the new university, instituted and paid for a student/scholar exchange program with American universities, particularly Michigan State University. Several of the present faculty received their graduate, and in some cases both undergraduate and graduate, education in the United States--and not only at Michigan State. In consequence of this enlightened program the university is one of the more international in Japan. There are small academic exchange programs with numerous Southeast Asian and Pan-Pacific schools.

With reversion of Okinawa to Japan in 1972, the university became a national university. When Professor Francis A. Richards of the Office of Naval Research (ONR) Tokyo visited the university in 1979 it was crowded in its original location, had no graduate program, and had only limited research facilities and effort (Ref 1). By 1983 the university had moved to the present splendid campus in Nishihara-cho, 20 minutes by car (1 hour during rush hour) in the Naha environs. It occupies a beautiful hilly site, one of the largest single campuses of any Japanese university. Its medical school and hospital are on an adjoining hill. The buildings are new, and new faculties and new buildings are being added regularly. The student body of 7,000 increases from year to year. Because Okinawans love their islands and are loathe to leave, and because of the lovely, beneficent, subtropical climate, the university is able to compete with the best Japanese schools for able native students. There are Masters degree programs in all appropriate departments. In 10 years the university plans to confer the Ph.D. Of the 766 faculty, 62 are in the College of Science, 63 in the College of Engineering, and 2 in the Marine Science Center. The College of Science has Departments of Mathematics, Physics, Chemistry, Biology, and Marine Science. The College of Engineering has Departments of Mechanical Engineering, Energy and Mechanical Engineering (mechanical engineering with energy conservation emphasis), Civil Engineering, Architectural Engineering, Electrical Engineering, Electronics and Information Engineering, and an interdepartmental program in Applied Mechanics and Mathematics. Quite properly, there is an emphasis on training and research in fields significant to the island environment--electrical power line structural and insulation damage by sea winds and typhoons (of which Okinawa gets plenty), wind resistant building structures, wind energy, solar energy, biomass, hydraulics, soil science, ocean science, tropical agriculture. But there are also active research programs in such universal fields as x-ray crystallography, powder metallurgy, computer science, high T_c superconductors, electronics, soft magnetic materials, and rare earth magnets. The author recently visited with engineering and physics faculty. Though teaching loads average two to three courses per semester and only Masters students are available in research laboratories, most faculty are active in research. To give some flavor of the activities and resources I will describe some of the work.

RESEARCH ACTIVITIES

Ceramic insulators isolate electrical power transmission and distribution lines. Under high voltage, especially in humid weather or light rain, wet salt deposits on insulator surfaces cause flashovers, power loss, and disruption of transmission. Yoshio Higashimori of the Department of Electrical Engineering finds that most of the salt is deposited by typhoons; as much as 0.03 mg/cm^2/h can be deposited during a typhoon (Ref 2,3). Wind velocity is an important ingredient--insulators on power lines in the lee of mountains are less contaminated. The higher the insulator is located the greater the deposition rate, and at high wind speeds and with no rainfall the precipitation is a maximum. Deposition is least on the bottom surface of suspended insulators, and shielding greatly reduces salt deposition on all surfaces.

Kiyohiro **Miyagi** of the Engineering Manufacture Laboratory specializes in high velocity impact, shock waves and high strain rate phenomena in materials, and high velocity compaction of metal powders (Ref 4-7). Metal (copper) powder is loaded into a die and subject to sudden, high velocity solid impaction by a punch. Upon impact, a shock wave is induced at the surface of the powder. It is the propagation of this shock wave that causes compaction of the powder. Though the propagation front is initially planar, wall friction reduces the velocity and retards the progress of the wave along the surface of the die. The wave front thus grows convex (viewed from the front) as it approaches the plug at the end of the die, and a convex wave is again reflected back from the plug as the wave echoes back toward the punch. The reflected wave thus reverses the curvature of the compaction. The result is that after a number of echoes back and forth and attenuation of the wave the density of the compacted powder is uniform across the cross section of the die, in spite of wall friction. Miyagi and coworkers demonstrate this in a series of high speed photographs of the moving shock front, and their theoretical analysis confirms that they understand the phenomenon.

For quantum well devices, semiconductor lasers, nonlinear optical mixers, and semiconductor superlattice devices of all kinds, the most important material is GaAs. This is because of its extraordinarily high electron mobility, high radiative recombination transition probability (unlike silicon), and because there are dopants, notably Al, which allow good lattice matching (Ref 8). Carrier lifetime, in electronic applications, and radiative recombination probability, in optical applications, are strongly degraded by dislocations and lattice defects. While dislocations are an inevitable consequence of even the slightest lattice mismatch in epitaxial superlattices, defects also occur even in single crystal pure GaAs and doped samples. These can be due to non-stoichiometry, growth, strain, and thermodynamic conditions. To improve device performance it is important to understand the morphology and the factors influencing the growth and number of defects. Takehiro **Maehama** of the Department of Electrical Engineering has long studied defects in GaAs (Ref 9-14). More recently he has developed a double incidence method for simultaneous and accurate determination of the refractive index and the angle of misorientation between a crystal surface and a symmetry plane (Ref 15).

Shosuke **Itomura** of the Department of Mechanical Engineering specializes in the solidification of cast iron. His early research confirmed that the volume fraction of graphite is independent of the solidification time, depending only upon the carbon content. With increased undercooling the solidification time decreases and the number of surface graphite nodules per unit area increases (Ref 16). In spite of years of effort in steel welding technology, cast iron remains a difficult material to weld. Because of the low reliability of cast iron weld joints, welding is mostly employed in repair shops rather than in manufacture. In arc welding, the most popular and practical process, the formation of white cast iron in the fusion zone causes weld cracking. To better understand the white cast iron solidification process, Itomura investigated the microstructure of white cast iron of various compositions at and near the eutectic as a function of cooling rate and cooling geometry (unidirectional solidification) (Ref 17). Itomura et al. demonstrate that the martensite start temperature falls linearly and significantly with reduced maximum heating temperature and conjecture that this is because of reduced carbon diffusion from the graphite grains to the matrix at lower heat inputs (Ref 18). (See Reference 19 for a description and many references on the martensitic transformation.) This implies that different regions of the heat-affected zone of the weld have different martensite start temperatures depending upon their particular thermal exposures. But the fracture always occurs in a region of the weld whose temperature has cooled below the martensite start temperature, and in fact always takes place in a region at which the temperature is a particular temperature (373 K), independent of the loading start temperature. The fracture occurs in a region of martensite structure of high hardness. Prof. Itomura is aided in his research by the cooperation of the Welding Research Institute of Osaka University and by Okinawa Cast Iron, Inc.

Yasumasa **Yamashiro** of the Electrical Engineering Department publishes widely on the magnetic and mechanical properties of rapidly quenched (splat cooled), iron based alloys (Ref 20-32). Si-iron alloys have been used in transformers, motors, and generators since 1900 and the beginning of electrical machinery. Today it continues to be widely used at low Si concentration. The research frontier is at higher Si concentrations. Silicon not only increases the electrical resistivity but decreases the magnetic anisotropy and the magnetostriction. Near 6.5 wt. % Si the magnetostriction is almost zero. Thus the coercive force and the hysteresis loss are low and the permeability is high. Silicon iron is also cheap. At 6.5 percent concentration it would be a first rate core material (in spite of an undesirable decrease in saturation magnetization) but for its poor mechanical properties. It is hard, brittle, and of poor ductility. It cannot be cold-rolled into sheets. But when the melted alloy is ejected onto a roller as a thin ribbon (10 to 100 micrometers) and rapidly quenched, the material is mechanically flexible. It should be noted that these ribbons are not amorphous; they are crystalline, and they retain their fine magnetic properties (Ref 33,34). Thus there has been a great deal of activity in perfecting the magnetic and mechanical qualities and in industrial application of high Si-iron ribbons. Yamashiro et al. investigated the thickness dependence (Ref 20) and Si-concentration dependence (Ref 22). At all thicknesses, tensile strength is higher than for the bulk alloy; it is maximum at a 60-micrometer thickness. Initial permeability increases by about 50 percent and maximum permeability by a factor of three when the ribbon thickness is increased from 10 to 100 micrometers. Initial permeability is virtually independent of frequency up to 100 kHz, above which it begins to drop. For each frequency there is a thickness at which total core loss is a minimum. A suitable thickness and Si concentration should be chosen depending upon application. But core losses are much lower than for grain oriented 3 wt. % Si-Fe steel commercially available. At lower Si concentration the saturation magnetization is higher, and 4.5 wt. % Si-iron rapidly quenched ribbon optimizes a number of magnetic properties. Grain texture and orientation can be improved by carefully adjusted annealing (Ref 25,27,29,30). Reference 27, an invited review article, is recommended.

For some applications one wants a material with a permeability independent of ambient magnetic field strength. Since 1928 Perminvar, a Co-Ni-Fe alloy, has been used for that purpose, but Perminvar is expensive and difficult to manufacture. Consequently the permeability of the purchased material is usually not quite constant. Since the constancy of permeability comes from the cancellation of changes in two competing sublattices, T. Yamamoto (Ref 35) conjectured that Fe-Ni-Si alloys might show the same magnetic response if they have Ni_3Fe and Fe_3Si sublattices as in the respective binaries and as in Perminvar. Sendai Perminvar, or Senperm (Ref 36), 8-12 wt. % Si/12-20 wt. % Ni-Fe, is cheaper and easier to make than Perminvar and has a more constant permeability, but it is not a practical industrial material because of its hardness and poor mechanical workability. Thereupon, when it became known that brittle bulk materials could be made as flexible, microcrystalline ribbons by rapid quench rolling (Ref 33,34), Narita, Teshima, Yoshida, and Yamashiro quickly fabricated splat cooled Senperm ribbons (Ref 21). The quenched ribbons are still somewhat brittle, but annealing for 3 hours increases their flexibility to a usable level. With 9 hours of annealing they become quite pliable. The permeability is high and constant in the as-quenched state and the magnetic properties are improved by annealing. In one example reported the permeability is 80, and flat up to 1 Oe. The permeability is also frequency independent up to 100 kHz, in fields up to 1 Oe.

Aluminum-iron (Ref 23,24) and cobalt-iron (Ref 26) are also magnetically attractive but brittle bulk alloys that can be made into flexible ribbons by splat cooling. Reference 28 summarizes the magnetic properties of rapidly quenched ribbons of Si-, Al-, and Co-iron. Co-iron has a high saturation magnetization and a particularly high Curie temperature. Pliable Co-iron splat cooled ribbons are now useful as a magnetic material in high temperature applications. As Co has a high magnetostriction, the material is attractive for magnetostrictive transducers, positioners, accelerometers, and magnetoelastic devices. Teshima et al. (Ref 31) and Yamashiro (Ref 32) have investigated the mechanical, magnetostrictive, and magnetoelastic behavior of Co-iron splat cooled ribbons.

In the Faculty of Science there are typically 12 faculty in each department--4 full professors, 3 associates, 2 assistant professors, and 3 instructors. Biology faculty work on coral reef and intertidal ecology, photosynthesis of mangroves and mangrove communities, as well as on traditional animal physiology and developmental biology. In Chemistry there is an emphasis on carbonate geochemistry and Ryukyu limestone formation and natural product chemistry. The Marine Science Department is active in marine natural products, fish and plankton ecology and biology, sedimentation, coral reef biology, tectonphysics, volcanology, and seismology. In the Department of Physics there are faculty working on plasma physics, elementary particles, magnetic properties of solids, low temperature physics, theory of phase transitions, quantum electronics, and optics. There is also research in the Department of Mathematics (operator algebras, complex manifolds, topology) and some research in the physical sciences by members of other faculties, for example, the Division of General Education. Altogether there is far more activity than can be reviewed in this brief survey. We mention only a few projects.

At a 1983 international conference on rare earth magnetism Katsuma Yagasaki of the Department of Physics gave an invited talk on the rare earth pseudobinary intermetallic compounds with Ag and In (Ref 36). The rare earths he investigated were Gd, Tb, and Dy in the compounds $RAg_{1-x}In_x$, with x between 0 and 0.5. The Tb and Dy compounds of the system are all antiferromagnetic; the In-rich compounds with Gd are ferromagnetic. The rare earths contain localized 4f electrons providing the magnetic moment and mobile s conduction electrons. It is the s-f interaction that orders the 4f moments. Thus to interpret the magnetic ordering on an indirect exchange, two band model one requires knowledge of the number of electrons and holes as the ratio of Ag to In is varied. To determine electron and hole densities Yagasaki performed Hall, resistivity, and transverse magnetoresistance measurements. It is the ordinary Hall coefficient which, coupled with resistivity measurements, allows determination of the numbers of electrons and holes. Interpretation of the Hall and magnetoresistance data is complicated by the large extraordinary Hall and magnetoresistance effects, coefficients proportional to the magnetization. Yagasaki is successful in rationalizing paramagnetic susceptibility, Hall, and resistivity data to obtain separate electron and hole densities. Internal compatibility and agreement of the data with experiment are very satisfying. The number of holes falls monotonically with increasing In (and linearly except in the Ag-rich Gd compounds), dropping by about 0.5 hole per unit cell per atom of In substituted. The number of electrons, 10^{-4} the number of holes, is a maximum at $x = 0.1$ for the Gd system and at $x = 0.2$ for the Tb and Dy systems but is so small that electrons should contribute only negligibly to the magnetic ordering. But explanation of magnetic orderings from the nodes and crossings of the RKKY functions is not successful. It should be recognized that this is the common outcome; RKKY calculations generally predict antiferromagnetism except at low carrier densities.

The last research project to be reviewed here is the work of Haruo Niki and Ryokan Igei of the Department of Physics, Division of General Education. Niki et al. (Ref 37,38) are performing nuclear magnetic resonance (NMR) on protons in the high T_c ceramic superconductor $YBa_2Cu_3O_{7-\delta}$ doped with hydrogen. NMR is a powerful tool for investigating the microscopics of superconductivity. Line width, nuclear spin-lattice relaxation time T_1, and Knight shift give detailed information on penetration depth, density of states of conduction electrons at the Fermi surface, and the magnetic state and sites of atoms. Large amounts of hydrogen can be absorbed into YBCO, but at levels of less than 0.2 H atom per formula unit the critical temperature and superconducting properties are unaffected by the hydrogen, which is then a good probe of the superconductivity of the unperturbed material. For example, proton resonance line width is extremely narrow from room temperature down to 170 K. This is dynamic narrowing because the hydrogen is diffusing through the crystal. Line width becomes abruptly broader below 170 K but remains of constant width between 150 K and 92 K. This is interpreted to mean that below 150 K the hydrogen atoms are trapped at vacant O(1) or O(2) oxygen sites in the Cu-O chains. Below $T_c = 92$ K the line width increases rapidly with decreasing temperature because of the distribution of magnetic fields due to flux vortex penetration. The temperature dependence of the spin-lattice relaxation time is particularly revealing (Ref 38). $1/T_1$ shows a fairly large enhancement at $0.93\ T_c$, followed by a sharp decrease with decreasing temperature. This suggests a superconducting energy gap of 600 K.

SUMMARY

The University of the Ryukyus has come a long way since its last visit by an ONR Far East representative 10 years ago. At its new spacious site the university is building buildings, assembling facilities and equipment, acquiring faculty and programs, and increasing enrollments. There is now a Masters program in most departments, and there will be Ph.D. programs another decade from now. Teaching loads are heavy for research, and as at most Japanese universities, research is badly underfunded. But the students are quite good, the faculty enthusiastic, and the administration supportive and eager to improve quality and reputation. Ten years from now the University of the Ryukyus will be proudly and competently on its way into the new century. The United States can be very proud of launching the first public university in the Ryukyus. It can be especially proud of having done so voluntarily as an occupying war power.

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STATISTICAL QUALITY CONTROL TECHNOLOGY IN JAPAN

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From 17 May to 1 June 1989, a survey team organized by the National Institute of Standards and Technology visited Japan to assess research and application of statistical quality control technology. The team explored the philosophy and conduct of total quality control (TQC) in Japanese industries, government laboratories, and national agencies. The philosophy and practice of TQC in Japan is quite different from that of the U.S. industries. Our findings are similar to the findings from "R&M 2000 Variability Reduction Process Trip to Japan" (Ref 1).

INTRODUCTION

The purpose of this visit was to assess the latest research and application of statistical quality control technology for product and process design and for manufacture in Japan. We soon found that isolated statistical applications are a very small part of the overall scheme of their industrial operations. The governing concept is total quality control (TQC). Quality control in Japan means *Total Quality Control* with everyone committed from top management to the lowest level workers in all departments, including design, sales, promotion, and service departments.

TQC activities in Japan have intensified over the years, in particular, after oil crisis in 1975 and the rise of the yen in 1987. Each time, Japanese industries braced themselves for worse economic conditions to come and practiced more intense TQC. In both instances, their economy did not decline but grew to higher levels of quality and productivity. To improve and to keep the well oiled machinery of their economy continuously running is becoming a national obsession; even the self-employed farmer talks about continuously improving processes for his products and harvest. The original idea of involving managers in quality control, based on measurement and analysis, was initiated in the United States during the 1942-1945 war effort. These ideas, originally expressed in a training manual written by the U.S. Army, were introduced to Japan by Dr. Deming in 1950. It was accepted by Japanese industrialists, and the concept has been expanded ever since. In the United States, management did not follow through on the success of the war effort. Although the use of quality technologies and supporting statistical methods in U.S. industries is now increasing, the concept of total quality control and the involvement of top management and the total work force in an integrated quality control team effort has not yet taken hold. Many U.S. leaders are convinced that the division of the total work force along specialist lines is the greatest barrier to progress.

National Research Laboratory of Metrology (NRLM) and Electrotechnical Laboratory (ETL) of the Japanese Agency of Industrial Science and Technology

Dr. Craig T. Van Degrift of the National Institute of Standards and Technology (NIST), Center for Basic Standards, Electricity Division, is currently a guest researcher at ETL. He joined us during the visit and explained the similarities between the work being carried out in NIST and ETL. NIST and NRLM/ETL work programs are very similar.

Dr. Hiroshi Yano, Director of the Mechanical Metrology Department, is one of the authorities on measurement control engineering in Japan. He is the foremost supporter and promoter in Japan of Dr. Genichi Taguchi's ideas. Taguchi's philosophy and approach to quality gained recognition in the United States after segments of AT&T, Ford Motor Company, and Xerox Corporation adopted some of his ideas. One purpose of our visit was to learn more of the Taguchi approach in Japan. We were told that the use of Taguchi's methods is concentrated in a few industries, particularly in firms located in Nagoya. Yano's laboratory is one of the places in Japan where these ideas are used.

Dr. Masayoshi Koike, Chief, Instrumentation Mathematics Section, of NRLM and his team demonstrated the use of the Taguchi approach to the design of computer and robot controlled plastic injection molding processes. A software system called CAMPS (computer aided measurement and process design and control system) supports planning and data analysis of statistically planned experiments in process design patterned after Taguchi's ideas. This is an excellent example of a systems approach in quality technology research. A realistic systems problem is used to stimulate and focus efforts on those quality technologies that are particularly significant. To accomplish this a system test bed and a team approach involving engineers, statisticians, and computer specialists are required. The purpose of such research is to produce a methodology and software for configuring sensors and measurements for process control and optimization.

Several people we visited at NRLM stated that their goal was to become the premier standards laboratory in the world. They currently view NIST in that regard (a view that might be taken with a grain of salt, considering who we represented). The injection molding project was an example of government/industry cooperation. The equipment was donated by the equipment manufacturer, who also supplied a researcher to cooperate with the NRLM staff for a portion of the project. This arrangement, which appears to be an excellent way to transfer technology from laboratories to industry, appears not to be as widely practiced at NRLM as it is at NIST and other research laboratories in the United States.

At ETL we discussed with Dr. Yoshitane Akiyama, Director of the Technical Information Office, the range of research activities carried out at ETL. We also saw a variety of projects in robotics, machine vision, and electronic device research. The visit to the robotics and machine vision laboratory was somewhat disappointing, as the research we saw was several years old and had been reported in English-language journals as early as 1983. One of the more active areas at ETL used to be their artificial intelligence and robotics software research efforts. The activity has apparently been much reduced since the fifth generation computer project was transferred to the Institute for New Generation Computer Technology (ICOT). In the areas of materials research and new electronic devices, however, it would appear that ETL is conducting world-class research. We saw an effort to develop a new voltage standard based on Josephson junctions that would provide a self-calibrating standard reference at relatively high voltages. The intent was to make voltage calibrations much easier and accessible to industry. As another example of their work, there was an announcement while we were in Japan that the group at the Tsukuba Laboratory complex working on laser research had developed the "Ashira system," which attained the highest laser beam intensities with one-sixth to one-seventh of the energy previously required.

Kanto Auto Works, Ltd.

Kanto Auto Works, Ltd., is a wholly owned subsidiary of Toyota Motor Company. It is located in Yokosuka not far from the U.S. Naval base. This factory assembles four different types of automobiles. Kanto Auto Works claims that this factory has the highest production record in the world for its size in space and in number of employees. (There are over 1,600 workers, about 150 managers, and about 70 engineers.) The working floor space is limited and very effectively utilized. To accomplish this, management maintains very tight control of materials delivery and handling. Just-in-time scheduling of all activities appears to be the norm rather than the exception.

The factory is highly automated. Four different car models are assembled concurrently on a single production line. Industrial robots used on the line differentiate among types of automobiles based on a schedule broadcast from a central control system. People are used to load some of the machines, but most of the machines are integrated in the flow line and loaded automatically. The most highly staffed areas are in the assembly of the automobile interior seating and in the final inspection area.

A fully assembled car comes out of the plant every 1.5 minutes. The factory operates with a goal of zero defects: every car that comes off the assembly line is, in principle, defect free. Any production line worker has the authority to stop the line if quality problems are observed.

While production is at a very high level, there is a constant search for opportunities to improve operations. Kanto Auto Works is in the process of building a new factory for robotic assembly of car interiors (currently the most labor-intensive part of production). Unfortunately, we were not able to see the inside of the new factory, which is nearing completion. The manager of the plant told us that much of the design of the new plant is based on suggestions from plant workers participating in QC circles.

The robots used at Kanto Auto Works are very simple as compared to what we think of as a robot in the United States. The robots very seldom use sensors, and the programming is primarily of the pick-and-place variety. There is a strong emphasis on straightforward, low-technology approaches to keeping processes in control. Many processes have been equipped with simple, often mechanical, devices for error detection and, less frequently, error compensation. There are highly visible status indicator lights at every work cell that are used to attract the immediate attention of maintenance personnel when required. The Manager of

Production said that most of the robotic engineering is not done locally but rather by a corporate-wide engineering group. He predicted that unless they expand their local engineering staff, they will have problems in the near future in dealing with the increased number and sophistication of the robots they are planning to install.

One significant difference between Japanese and U.S. industries is the way in which the quality of incoming parts is controlled. Often, suppliers are members of the same conglomerate. Japanese industrialists do not like suppliers over whom they have no control. They prefer trusted subcontractors and often pay a premium cost to maintain a supplier relationship.

At the workplace, as we observed at Kanto Auto Works, workers take only two 10-minute work breaks, one in the morning and one in the afternoon; the lunch break is only 20 minutes.

One interesting aspect of TQC as practiced at Kanto Auto Works concerns the introduction of new products. The standing procedure when, for instance, a new carburetor system starts production is to train everyone who will be in any way involved with the production of that system, be it worker, engineer, or manager, to entirely assemble and explain the operation of that system. According to the Manager of Production, this policy has had a dramatic effect on the attitude of the production staff; they consider themselves all members of a team producing a carburetor, rather than individual workers concerned solely with their personal efforts.

There is no evidence of socializing on the job; every step has a purpose in the production process.

Union of Japanese Scientists and Engineers (JUSE)

We met with Mr. Junji Noguchi, Executive Director of JUSE. He has been with JUSE for many years, and his knowledge about and contributions to the advancement of quality control in Japan are unparalleled.

JUSE was established in 1946, right after World War II. Japan was eager to rebuild industries and to use statistical quality control methods in many of the leading manufacturing companies. In 1962, JUSE was consolidated under an umbrella of formal recognition by the Science and Technology Agency of the Japanese Government to better cope with the rapid technical advancement of Japanese society. JUSE is not a government agency. It is a nonprofit organization supported by membership and the sale of services and technical literature; it is financially independent. It is governed by its corporate members, including manufacturing, construction, and service industries. Most of the major corporations in Japan are members of JUSE. This is an organization unique to Japan; it is devoted almost entirely to the promotion of quality control in Japan. JUSE's function is to educate all levels of the population in concepts of statistics and total quality control.

JUSE sponsors both domestic and international technical meetings. For example, each June and December JUSE sponsors a general quality control meeting [a counterpart in the United States is the annual meeting of the American Society for Quality Control (ASQC)]. The June 1989 meeting was scheduled for 13-14 June (eight parallel sessions in 2 days) in Hiroshima; its Proceedings were published as a special issue of the monthly magazine *Hinshitsu Kanri* (in earlier years this was translated as "Statistical Quality Control," but now it is translated as "Total Quality Control"), June 1989, Vol 40. This issue contains 90 articles in 441 pages. Topics presented include product improvement, quality assurance and the development of new products, process improvement, software, statistical quality control (SQC) methods, reliability, process control, etc. There is no section on new theoretical development in SQC. Emphasis is on clever usage of statistical methodology for quality control. Presentation of the papers is uniform in style for every topic, reflecting a national approach to education and training in QC methods. Each application follows a cycle: (1) understand the problem, (2) experiment, (3) collect data, (4) perform statistical analysis (regression, factor analysis, multivariate analysis, etc. are used), (5) improve and then return to step (1) for an additional iteration. The procedure is called PDCA (plan, do, check, action), or the Deming Circle (a result of earlier teaching by Dr. Deming). Illustrations (graphs and diagrams of the seven tools of QC) are frequent. Figure 1 illustrates the PDCA approach.

JUSE administers the prestigious Deming Prize, initiated in 1951, the year after Deming taught his first course in Japan. JUSE also administers the Japan Quality Control Medal and the Ishikawa Prize. All the activities are governed by advisors and working committees consisting of university professors and representatives from member corporations.

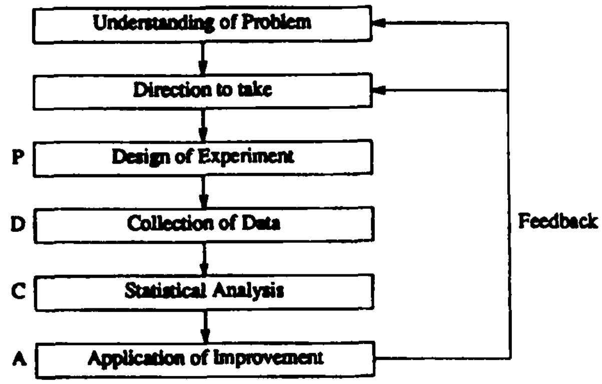

Figure 1. The PDCA approach.

JUSE has played a significant role in industrial advancement at Japan and is the driving force for research, development, education, and dissemination of information on mathematical and statistical methods for quality improvement.

Since 1951, JUSE has published a quarterly journal, *Reports of Statistical Application Research*, in English. Since 1987, JUSE has published a newsletter, also in English. Also JUSE publishes several monthly magazines in Japanese: *Hinshitsu Kanri* (Total Quality Control), *Engineers*, *FQC* (Quality Control for the Foreman), and *QC Circles* (for production workers, office workers, etc.). The June 1989 issue of *QC Circles* is devoted to QC circles of office workers to control inefficient office practices; 18 different cases with solutions are discussed. Some articles in *QC Circles* are written by high school graduates and could be published in ASQC journals in the United States. They all follow the standard PDCA practice.

As of May 1989, 283,693 QC circles representing 2,282,749 members are registered at JUSE. The July 1989 issue of *QC*

Circles is devoted to papers for "nurturing a willingness," telling how to cultivate an environment in which workers enjoy quality improvement activities. The magazines always contains a section of success experiences and a continuing education section. In this issue, instructions on constructing Pareto charts are presented in a step-by-step fashion. This continual repetition of simple QC concepts is typical of the Japanese approach of inculcating QC practices into the entire work force.

The May 1989 issue of the Japanese magazine *Engineers* contains three main papers: "Treating a Customer-Centered Culture for Service Quality--It helps to think of the service as a product," by Robin L. Lawton; "Quality Plan Development: A Key Step Toward Customer Enthusiasm," by J. Stephen Sarazen (both translations into Japanese of articles originally published in *Quality Progress*); and "A Report of the Seven Management Tools for QC Seminar in the United Kingdom," by Ryoji Futami. Both translated papers are directed toward considerations of customer satisfaction and give clear directions for actions to take. The papers appeal to Japanese readers since a stated goal of all Japanese industries is customer satisfaction. The magazine concludes with a section of announcements of symposia, seminars, new publications, and software.

There are many other JUSE publications. For example, there are books in reliability engineering for industry, translations of English books, and theoretical statistics texts, to name a few. The book titled *Check Points for Taking QC Education and Examination* by Isamu Itsukage (published in 1989) lists 47 items to be checked in implementing a TQC program. JUSE also produces a pocket calendar, which has an appendix containing concise information on: "Business Operation and TQC," "What is QC," "What are QC Circles," "Statistical Tables," and other sections of interest to persons involved in TQC. Committees of JUSE publish books; for example, the failure analysis committee published a *Guide Book For Failure Analysis* in 1986.

Since 1985, JUSE has initiated new education and training courses for international groups. In October 1989 two courses were offered: "JUSE International Seminar on TQC for Senior Management" and "Seeing is Believing," the Second JUSE International Seminar on TQC.

Japanese Standards Association (JSA)

JSA was founded as a nonprofit institution in 1945 under the Japanese Ministry for International Trade and Industry (MITI) to propagate industrial standardization and quality control to all Japanese industries. JSA is similar to JUSE but under the sponsorship of a different ministry of the Japanese government. JSA operates with income from the sales of publications and other sources, such as lecture fees and corporate membership fees (as of March 1988, there were 8,615 member corporations). The publications of JSA are very noteworthy. A large number of these publications are Japanese Industrial Standards (JIS). JIS Z8101 defines total quality control as "a system for producing a quality product or service which satisfies customers in the most economical way." This system includes: market research, engineering research and development, design of the new product, planning, marketing, production, testing, sales, after-service support, worker relations, and education. All the terms related to TQC are standardized in Japan and published by JSA.

JSA publishes many booklets on quality control on different subject matters that are suitable for top management down to blue collar workers. Noteworthy JSA publications (all in Japanese) are:

- *Statistical Tables and Formulas with Computer Applications*, JSA-1972 (720 pages). These tables are not copies of previously published tables; they were recomputed and checked for accuracy.

- *Hand Book of Quality Control*, 1977 (938 pages). This volume covers quality control in Japan, including statistical theories with examples of applications and a history of the development of QC.

- *Lecture Series in Quality Engineering*, Vol 1-7, General Editor, Genichi Taguchi, 1988-1989. These volumes cover: (1) development and planning, (2) production, (3) signal to noise (SN) ratio for quality evaluation, (4) experimental design, (5) examples (Japanese), (6) examples (European and American), and (7) examples in measurements. JSA is organizing a seminar series based on these books. To date, volumes 1-5 have been published.

JSA has organized a quality engineering research group (QRG) that meets once a month on the first Thursday from 0930 to 1630. At these meetings a lecture is given by Professor Taguchi in the morning and the members share their experiences in the afternoon.

JSA also publishes a series of small booklets (all in Japanese) on quality control, including theoretical statistics and introductory texts for production workers. Examples include:

- Kurogane, K. (1986), *Introduction to Quality Control: Total Quality Control and Practice*, 4th edition (122 pages).

- Ozeki, K. (1988), *Introduction to Quality Control: Improvement and Practice*, 8th edition (110 pages).

- Asaka, T. (1988), *Foundation of TQC*, 9th edition (153 pages).

- Sugimoto, T. (1988), *Quality Control*, 4th edition (62 pages).

- Kurogane, T. (1986), *Operation and TQC* (38 pages).

- Makabe, H. (1988), *Quality Assurance and Reliability* (20 pages).

These booklets are relatively short and are designed for easy reading such as on a commuter train. It should be noted that some of these booklets are now in a 9th edition. They are extremely popular.

Matsushita Electric Industrial Company, Ltd.

The VCR factory is an impressive facility. The production floor is configured as a flow line and is fully automated except for monitoring and setup personnel. On the main floor, there are three lines that assemble over 4,000 components per VCR. The chassis are prepared in a part of the building we did not visit. Each production line can handle only one product model at a time. However, a line can be changed to produce any other model amazingly quickly in an average of 3 minutes. The operations are all designed to use the same production robots, and the unit processes are controlled through downloaded programs to the individual robots.

There has clearly been a great deal of attention given to the design of the facility and to the products it is to produce. As mentioned above, all models of VCRs are assembled using the same production equipment, usually with no change to equipment setup. Every step of the process is designed to take a standard length of time, so the problem of balancing work-in-process inventory against machine utilization effectively does not exist. The assembly processes varied widely and include operations such as screwing, loading of springs, gluing, soldering, and insertion. Nevertheless, there is a uniformity to the processes that clearly speaks of a concern for standardization. All robotic operations are done from above; there is not a single case of having to fight gravity. With only one or two exceptions, every operation uses the same model robot; only the end-effectors change. Every operation is clearly visible to an observer. Finally, again with only a few exceptions, quality is ensured through in-process sensing rather than post-process inspection.

Unlike Kanto Auto Works, the robotic technology in use at Matsushita is highly sophisticated. Nearly all steps in the process involve some sort of sensory-interactive control and/or sensor-based process verification. During the time we spent observing the line (about 2 hours), there were perhaps three instances where we observed sensors detecting a production problem. When such a problem arises, a person arrives within a few seconds to deal with the problem. This gave us a chance to observe the man-machine interactions, which have also been well engineered. Each flow line is arranged in a "U," with someone to monitor the line stationed in the center of the U. Each station, which performs a single operation, has a poster hanging over it that clearly illustrates what pieces of the VCR are involved in that step. The person need waste no time figuring out what was supposed to happen. Every problem we observed was a case of something (a spring, feed wire, etc.) having gotten stuck and needing to be freed, and it was fixed in under 10 seconds. The VCR in question was simply moved back in the flow line to undergo the operation again.

The VCR factory has one area where significant improvement seems possible. The factory has an imposing automated storage and retrieval system to manage a large inventory of components and completed products. The need for this system was not satisfactorily explained to us. The system is tied into the material handling facilities for all three flow lines and for the rest of the factory building. While the system and the computer interface to it are quite sophisticated and efficient, one gets the feeling that further efficiencies could be gained by working out a way of eliminating the system itself.

We had a very informative discussion with senior managers of the Corporate Quality Assurance Division (CQAD) of the Matsushita Electric Group. This division employs about 120 people and has an annual budget of about ¥2 billion (about $14M). The primary responsibility of the CQAD is to work with the other divisions of the company to help ensure product quality. In most U.S. companies, the function of a quality assurance division is cast in terms of ensuring that a product as produced conforms to its original design. The definition used at CQAD is much more general--a product must conform to customer expectations and desires. The most marked effect of this definition is that the Quality Assurance Division has responsibility for gathering market information on existing products, a function usually found in marketing divisions in U.S. companies. The CQAD has, in addition, the following functions: product evaluation, life-cycle research, planning of quality management, quality administration (domestic and overseas), quality counsel, calibration and other equipment-related measuring tasks, technical promotion, and packaging evaluation.

In touring the CQAD, we saw many facilities for product testing. The usual approach to product testing is to bring in test subjects who represent typical users and have them use not only Matsushita products but a wide variety of competitor products as well. (We must sadly report that U.S. appliances were deemed to be so uncompetitive that they did not need to be tested. U.S. computers, on the other hand, were being extensively evaluated.) The managers proudly emphasize that testing of Matsushita products is done in the name of the company president.

The CQAD has developed a system for managing quality data that appears to be extremely valuable to the company. Every quality-related decision made during the product life cycle is recorded on a standard form. These forms are indexed, electronically imaged, and stored on computer. This quality data base is periodically analyzed statistically to identify problem areas. It is also available online for historical research at the start of any new design. Our hosts appeared reluctant to share any technical details concerning this data base. Its value in enabling TQC clearly makes this data base an invaluable corporate asset.

The Matsushita Museum of Technology is a facility the company uses to display its latest technological developments as well as the company's technical history. The latest Matsushita products, many of them at an experimental or prototype stage, are demonstrated to a steady stream of Japanese and international visitors. This museum is not only an excellent form of advertising and public relations but is quite likely a source of feedback to market research staff regarding the interest shown in and comments regarding the various experimental products.

DISCUSSION

The history of advancement of quality control in Japan shows clearly that success was not achieved overnight. The Japanese make step-by-step improvements every year with clearly targeted goals each year. All workers know what their goals are and work to achieve them. Statistical methods are utilized on the way, and everyone involved has some level of statistical education and understands basic statistical ideas and methods of quality control. In Japan "everyone" means literally everyone from the company president to the janitors. Success of Japanese industries appears to be founded on the following factors.

Human Relations (Cooperation)

- The trust between workers and management is mutual. All managers and workers consider that without each other there would be no jobs and no profits. It is essential to cooperate with each other.

- Management behavior clearly establishes trust between management and workers. (However, there are indicators that group consciousness sometimes does conflict with individual needs.) To help build this trust there are no executive dining rooms; the CEO dines in the same dining room where every worker eats. Every worker (including the CEO) receives twice a year bonuses depending on the success of the company. In Japan, the CEO would not get a bonus while workers are asked to take a pay cut.

- Management considers the workers to be knowledgeable about the product and its manufacturing process. Suggestions from workers for improvement are encouraged and considered seriously. Frequently over 80 percent of the suggestions from the workers are implemented.

- When a production failure occurs, management puts all of its energy in finding the cause of the failure and correcting it. Fixing blame is avoided on the grounds that doing so would interfere with accomplishing quality goals.

Education

- Japanese high school graduates have an education comparable to 2-year community college graduates in the United States. They go to school 5-1/2 days a week, for about 7 hours each day, and slightly over 10-1/2 months a year. Science education is mandatory. The literacy rate is 98 percent. There is, however, a concern with the level of stress among school children.

- Japanese businesses consider educating workers as an important investment. The idea of lifetime employment goes hand in hand with this investment.

- Most workers are assigned to every job on the floor so that they know the whole procedure of manufacturing a particular product. In fact, a worker at the Kanto Auto Works is expected to be able to assemble a car by himself.

- Almost all workers have continuing training courses in quality control.

Concept of TQC

- TQC means that everyone is involved in quality control practice. The TQC operation is headed by the CEO. The concept of statistical methods is understood by everyone and applied to every operation company-wide.

- The goal of the company is known to everyone. Usually it is posted for everyone to see, and everyone works to achieve this goal. The nearest thing to this in the United States is the United Way Campaign (UWC): for a period of 1 month or so in the fall, U.S. companies post their goals for contributions and almost everyone participates to achieve this goal. There is a victory celebration and everyone has an opportunity to feel satisfaction in a corporate job well done. The Japanese approach to TQC has much in common with our UWC.

- TQC means quality control by everyone. It means QC for management, QC for engineers, QC for design engineers, QC for workers, and QC for sales operations. It needs the total cooperation of everyone involved.

Goals

- The primary goal is customer satisfaction and production of quality goods. This philosophy is basic and rooted in the Japanese culture. The Japanese have always treasured quality goods. Their export of poor quality products before the war and immediately after the war is not a true representation of the Japanese emphasis on quality. Today the national viewpoint is that if customers are satisfied, profits will follow.

- Competition is very high in Japan because many companies make the same kind of products.

- Japanese organizations seldom set half-way goals. Whether it be in manufacturing, finance, standards, research, or education, the goal is to be the best in the world.

Application of Statistical Methods

- The basic concept in Japan is to observe and to analyze data with simple statistical tools. The widely used approach is "the seven tools of quality control." Many booklets on this subject have been written and are widely read by both top management and workers. These "seven tools" are described briefly in Appendix A.

- Japanese industries strive for zero defects in production. To do this they test 100 percent on carefully selected measures of production quality. This is a specific example of the general Japanese emphasis on doing things right the first time.

- Quality control applies not only to production but to many other business operations as well. The newest group to enter the practice of quality control is the group of service organizations, for example, banks, restaurants, department stores, and even McDonalds in Japan.

- Taguchi's philosophy of engineering design and his approach to the analysis of data (his initial publication was in 1966) gained fame as the Taguchi Method in the United States. The timing of his arrival in the United States was concurrent with the recognition of the need of good quality control practice in the United States; it was a time when any application of systematic statistical analysis would have made a significant contribution. Taguchi has a long history in the practice of QC in Japan; for example, he was the first to use orthogonal array designs in Japan, and his book *Design of Experiments* is widely used in Japan. However, his approach to data analysis (SN ratio method) is not well appreciated in Japan. There is some controversy with regard to the theoretical validity of his approach among theoretical statisticians in the United States. Such criticism also exists in Japan. The May issue of *Standardization and Quality Control* has an article titled "Taguchi Method from the Viewpoint of a Statistician," which is a discussion between Professor Taguchi and Professor K. Takeuchi (Tokyo University). A summary of this discussion is in Appendix B.

FUTURE STATISTICAL RESEARCH

Quality control experts in Japan are now questioning the directions they should take in the future. A recent paper by Professor Tadakazu Okuno, Provost, Tokyo Science University, states that "in spite of great advancements in technology, advanced statistical methods have not been utilized to their full potential" (Ref 2). Basic concepts, he states, should be improved. He points out that the time-honored seven tools of quality control should be improved, for example, by replacing histograms with stem-and-leaf displays, which give more information. He also thinks Tukey's data analysis methods (Ref 3) should be used along with multivariate analysis. Okuno defines the "seven new tools of quality control" as follows:

(1) Stem-and-leaf display
(2) Letter value display
(3) Box-whisker plots
(4) X-Y plotting
(5) Resistant line
(6) Median polish
(7) Smoothing

These seven new tools should not be confused with the "seven management tools for quality control" developed by a committee of JUSE headed by Professor Yoshinobu Nayatani. Okuno points out that statistical methodology is a most important factor of the practice of quality control and that one must not forget how to apply the iterative PDCA statistical cycle methods.

Okuno asserts that production technology has advanced much faster than quality control technology and that the "zero defects" goal can be satisfied by using online data collection methods and online feedback based on new techniques rather than 100 percent inspection.

In particular, the Toyota SQC Research Group has been studying the method of multivariate analysis in relation to their problems since 1977. They published a book, *Multivariate Analysis for Industries*, in 1986, selecting some examples from their experiences. For example, multivariate analysis was used for the analysis of process factors for auto body painting, for the analysis of materials requirements in the planning stage, for noise analysis at the testing stage, the stamping of body pieces at the production stage, etc. They stress the importance of the acquisition of accurate relevant information. Also they stress careful analysis of data from all points of view, such as data reduction methods, Tukey's exploratory data analysis, and use of the basic seven tools of quality control.

SAS software is used extensively in Japan. Initially there were many in-house statistical software packages, but the consensus of Japanese is that SAS is excellent and it satisfies their needs.

SUMMARY AND CONCLUDING REMARKS

The United States has as much advanced manufacturing technology as Japan, but the United States does not practice statistical quality control in the broad and coherent national fashion of Japan. The United States can learn from Japan that Total Quality Control technology can be used effectively in achieving quality goals. It is our perception that U.S. research emphasizes general results that can be applied to many situations. In Japan, research on particular conditions related to particular products is emphasized. However, Japan is changing as we observed at the National Laboratory in Tsukuba, where much general purpose research is underway. The United States is also changing, as many U.S. national laboratories are emphasizing technology transfer to industries.

U.S. government agencies that fund research should encourage this change by accelerating their funding of systems research in quality technology generic to particular industries. Such systems research would make use of a laboratory process test bed and a team approach involving engineers, computer specialists, and statisticians and would be oriented to producing a technology for process design and optimization.

We were exposed to such research approaches at NRLM; we suspect that Kanto Auto Works' new production line is founded in such research experience.

We cannot and do not need to transfer everything from Japan. Nothing is perfect, and even with Japan's industrial success, there is a dark side. The Japanese total commitment to the job puts great stress on the family, on the role of women, and on Japan's relations with other nations.

However, we should carefully examine Japan's use of QC techniques to identify methods that can be used to advance quality control in the United States while recognizing that there is still room for improvement in these methods. Our survey of Japan's use of QC techniques leads to the following perspective on U.S. needs:

- Most important for the United States is the education of every involved engineer and manager in TQC philosophy and techniques. Everybody should know how to collect data, how to analyze it, and how to look for significance.

- A timely editorial appeared in *Science*, June 2, 1989, titled "Teaching Statistics to Engineers." It emphasizes the importance of statistical education for U.S. engineers. This editorial should be given wide distribution to promote the development of statistical thinking in engineering education.

- U.S. management must create a cooperative environment and take the lead in the practice of quality control. Achieving the high standards set by Japan is not possible without the total commitment that can only flow from top management initiative.

- It is also important to encourage investment by large industries in the United States to help promote technical education, including data analysis and experimentation, at local precollege schools. In this way, competent future workers can be assured.

- It is important that government agencies, professional societies, and industry give national leadership in bringing quality technology to engineers in industry on a continuing and comprehensive basis. JUSE provides a model for institutionalizing such leadership, as does JSA. The new Congressionally commissioned Baldrige Award is another relevant model. The land-grant universities also have relevant experience. In particular, the Department of Defense should be among the leaders in establishing a coordinated national effort to disseminate quality technology information in a timely, continuing, and comprehensive national fashion.

- Government research funding agencies should accelerate their support of a systems and cross disciplinary research approach to the further development of quality technology.

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Appendix A

THE SEVEN INDISPENSABLE TOOLS FOR QUALITY

In order to achieve quality goals, it is essential to determine the state of the process from data. The quality of a process can be improved by accurate measurement and corrective action. Problems must be identified as soon as they occur. The so-called seven basic tools of QC are used in Japan to fill this need. It was reported that the use of these seven tools solves a majority of the problems that arise in Japanese industry.

These methods are graphical and are:

(1)	Easy to apply	Anyone can make a diagram with a little practice.
(2)	Easy to understand	Results are transparent on the graph in most cases.
(3)	Used by everyone	To promote coordination among all participants.

The seven tools are:

Histogram	Pareto Diagram
Check sheet	Scatter Diagram
Stratification	Cause and Effect Diagram
Control Chart	

The standard approach to solving quality control problems is:

(1) Investigation of the ongoing process

Find problem areas	--	Pareto diagrams
Find existing condition	--	histogram, scatter diagram, control charts
Find cause and effect relations	--	cause and effect diagrams

(2) Analysis of data

Stratification of data	--	histogram, control charts, scatter diagram
Correlations	--	scatter diagram, control charts
Changes in time	--	control charts, check sheet

(3) Take action

Corrective action may be obvious; if not,

use experimental design to find the corrective action.

(4) Confirmation of the corrective action

Are there favorable results?	--	control charts, check sheet, Pareto diagram

(5) Standardization and QC

Is operation normal?	--	control charts, check sheet

The above steps are repeated until the operation reaches the desired level. The level should be upgraded each time to improve the operation continuously.

Appendix B

A SUMMARY OF THE ARTICLE TITLED "TAGUCHI METHOD FROM THE VIEWPOINT OF A STATISTICIAN"

Professor Takeuchi compares Fisher's concept of experimental design to Professor Taguchi's concept. Fisher's ideas were motivated by experiments in agriculture where the purpose was to increase the value of the mean (increase production). Taguchi's idea is to reduce variability (increase product robustness), allowing the mean to be corrected in the final engineering process. So, the Taguchi method is experimental design with a different motivation. In any experiment or production process, there are always random errors, which may or may not be significant. It is important that statisticians (including users of Taguchi's approach) study the properties of these random errors by statistical theory. Regrettably, most statisticians in Japan paid little attention to Taguchi's ideas (the initial idea was presented in 1966). Takeuchi agrees with some of the criticisms raised by Professor Box and others, but he also thinks some criticisms are based on a misunderstanding of words. Taguchi agrees with Takeuchi's assessments. Further, Taguchi states that we should study the error between the observed SN ratio and the ideal engineering process. The problem is how to estimate this error and how to collect proper data. Taguchi calls any departure from the ideal products or ideal process "noise." Taguchi considers noise as a measurable factor that does not contain random error. On the other hand, Takeuchi considers that it may contain random error because there may be some factors in the noise that are unknown. Taguchi stresses robustness in the parameter design and this point is the biggest difference between classical experimental design and Taguchi's design. Taguchi considers that some problems can be addressed only as engineering problems or calibration problems and that statistical approaches are not helpful in these situations; here his ideas diverge from the ideas of statisticians. The editors agreed to have more discussions, further studies, and further publications in future issues.

FOURTH INTERNATIONAL CONFERENCE ON SCANNING TUNNELING MICROSCOPY/ SPECTROSCOPY (STM '89)

R.G. Brandt, R.J. Colton, C.R.K. Marrian, J.S. Murday, and J.A. Stroscio

STM '89 focused on the exploitation of STM and its related technologies. The conference featured sessions on semiconductors, metals, biological molecules, superconductors, electrochemistry, lithography, atomic force microscopy, theory and practice of tunneling tip, new concepts in proximal probe instruments, and practical applications of tunneling tip.

INTRODUCTION

The Fourth International Conference on Scanning Tunneling Microscopy/ Spectroscopy (STM '89) was held in Oarai, Ibaraki, Japan, on 9-14 July 1989. This conference focused on the exploitation of STM and its related technologies (so-called **proximal probes** for their common feature of positioning and moving two surfaces with subnanometer precision). The incredible growth of the conference continued, with the 220 papers this year contrasting with 150 in 1988 and 100 in 1987. Perhaps not surprising was the fourfold growth in the contributions from Japanese investigators. The conference featured sessions on semiconductors, metals, biological molecules, superconductors, electrochemistry, lithography, atomic force microscopy, theory and practice of tunneling tip, new concepts in proximal probe instruments, and practical applications of tunneling tip.

SEMICONDUCTORS

There were three regular sessions and one poster session on semiconductors. This was the largest single topic at the conference since historically the majority of the first STM work focused on semiconductors. The STM images of the various semiconductor surfaces displayed at the conference typically show exceptional atomic resolution due to highly localized charge distributions on semiconductors. The first session was started off by Becker (AT&T Bell Labs), who showed high resolution images of steps and domain boundaries on silicon surfaces and compared them to computer simulations to extract the amount of contraction in the surface layer. Mo (Univ. of Wisconsin-Madison) gave a paper on Si on Si epitaxy where he was able to estimate the Si self-diffusion coefficient of 10^{-13} cm^2/sec. He also showed that with Monte Carlo simulations the shape anisotropies observed in the growth were not due to diffusion anisotropies but from anisotropic interactions.

The second session was led off by Hashizume (Univ. of Tokyo), who gave a paper on alkali metal adsorption on Si surfaces. For Li adsorption, chain formation perpendicular to the Si dimer rows was observed. The chain axes are rotated 90° to what one might intuitively expect, where the atoms would go in an open furrow on the surface, as seen, for example, with the one-dimensional Cs chains on the GaAs(110) surface reported by Stroscio (National Institute of Standards and Technology (NIST), Gaithersburg). Anisotropic surface interaction is used to explain the chain growth on the Si(100) surface and is common to other adsorbates on this surface, as seen with Ga adsorption, reported by Baski (Stanford Univ.) in this session. An interesting paper was given by Wiesendager (Univ. of Basel, Switzerland) on the comparison of atomic force microscopy (AFM) and STM in imaging charge density waves in transition metal dichalcogenides. He found that the charge density waves were absent when using the AFM, while the STM was able to image them. This was surprising since in the repulsive force mode the AFM is also sensitive to the tails of the charge density, similar to the operation of the STM. Dr. Wiesendager proposed that the charge density waves were absent due to the applied force or pressure used in the AFM experiment.

The third session was opened by a very interesting paper by Hamers (IBM Yorktown Heights), who presented results on laser-assisted STM. In this paper Hamers showed that a nonequilibrium population of photogenerated carriers could be detected with tunneling spectroscopy (a similar result was presented for GaAs by Neuman (Univ. of Heidelberg, FRG) in the poster session). The extension that Hamers showed was that the surface photovoltage, which is the amount of band bending change induced by the presence of photogenerated carriers, could be imaged simultaneously with the topographic image using a gated feedback technique. In imaging the surface photovoltage Hamers showed that the two halves of the Si(111) 7x7 have a different photovoltage signal. He also showed that the power spectrum of the photovoltage could be used as a local probe of carrier lifetimes, where he observed higher rates for carrier recombination on defected regions of the surface.

Most of the other semiconductor papers and posters reported on metal-semiconductor and semiconductor-semiconductor systems. GaAs epitaxy, for example, was reported by Biegelsen (Xerox, Palo Alto). Demuth (IBM Yorktown Heights) showed in a poster the advantages of using Fourier transformed images to get at weak signals in the STM images. Stroscio (NIST, Gaithersburg) presented a poster showing the dispersion of evanescent gap states in GaAs, resulting from wavefunction continuity between metal and semiconductor surface regions, using spectroscopic imaging techniques. An exactly similar application of using energy resolved spectroscopic imaging was applied to gap states, but in superconducting systems, in regions of the vortex cores by Hess (AT&T Bell Labs).

METALS

Kuk (AT&T Bell Labs) started off the session on metals with a discussion of the surface band structure of metals and the use of the jellium model to interpret STM images. It was found that some electronic bands such as d-bands are too localized (as predicted by theory) to be observed by tunneling spectroscopy and some bands reveal large dispersion with long decay lengths. The other half of the talk dealt with the study of oxygen chemisorption on Cu(110). He found that O atoms grow at low coverage on terraces as long isolated rows. At coverages >0.2 ML, one begins to see some 1x2 structure; at coverages >0.3 ML, one begins to get a second adsorption site. Ogletree (Lawrence Berkeley Lab) studied the chemisorption of sulfur on Re(0001). The image consists of hexagonal rings of sulfur arranged on a $2\sqrt{3}x2\sqrt{3}$ R30° lattice. The sulfur overlayer was stable even after the tip made contact with the sample. Rousset (Univ. of Paris) studied the adsorption of sulfur on stepped Cu surfaces. She observed two coexisting superstructures of sulfur, namely, p(2x2) and c(4x2). On Cu(1,1,1) sulfur adsorption destabilizes the [011] steps, resulting in step faceting. On Cu(8,1,0), the [001] steps are stable under sulfur adsorption. Frenken (IBM Watson) studied the thermal roughening of Ag, Cu, and Ni (115) surfaces. He used STM to "watch" the metal surface roughen by the proliferation of kinks in step surfaces. This occurred at a roughening temperature $T_r \approx 0.60\ Tm/k_B$.

SUPERCONDUCTORS

In principle, the STM can be a valuable tool in the study of high temperature superconductors, providing information about atomic surface structure and electronic density of states. However, measurements made on polycrystalline samples often reveal properties that are not intrinsic but due to material inhomogeneities or grain boundaries. STM studies on single crystal samples of Bi-Sr-Ca-Cu-O were reported by Nogami (Stanford Univ.) and by Tanaka (Nippon Steel). These two groups concluded that the freshly cleaved surface exposed an insulating Bi-O plane; the atomic positions within this plane were accurately determined. STM images of thin film samples of chemical vapor deposition (CVD) grown Bi-Sr-Ca-Cu-O are also consistent with a surface that is primarily Bi-O. These results help explain the difficulty in establishing contact with the Cu-O planes where the superconductivity is believed to reside.

Kent (Univ. of Geneva) studied thin films of Y-Ba-Cu-O by a related technique called scanning tunneling potentiometry (STP). In this technique the sample topography is measured as in the usual STM. In addition, a dc current is passed through the film, and the local voltage drop is measured during periods when the tip-sample voltage is zero and no tunneling current could otherwise flow. The resulting potential image consists of a series of terraces of approximately constant potential separated by steps where the potential changes abruptly; the terraces can be identified as the superconducting grains and the steps as the insulating barriers that give rise to resistivity and degraded superconducting properties.

The most dramatic use of the STM in the study of superconductivity was reported by Hess (AT&T Bell Labs). He was able to image the magnetic flux lattice in a type II superconductor by differentiating between superconducting regions where an energy gap occurs in the current-voltage characteristic and normal core regions that have no energy gap. The images he obtained were consistent with those obtained by the decoration technique using iron filings. However, he also observed several unexplained phenomena. In particular, at large magnetic fields just less than the upper critical field when the vortices are close together, a sublattice appears to develop with new vortices occupying positions at midpoints in the original fluxoid lattice. This may be a new phenomenon not previously seen by other techniques or predicted by theory, or perhaps merely an artifact due to some peculiarity of the tunneling, such as a multiple tip effect.

SOLID/LIQUID INTERFACES

The STM is beginning to emerge as an important tool for in-situ studies of the solid/liquid interface during electrochemical reactions. Initially, there were problems associated with large Faradaic currents overwhelming the small tunneling current and with deterioration of the tunneling tip by electrochemical reactions. These difficulties have been overcome by coating the tip with a glass or polymer (only the point of the tip is exposed) and by careful control of cell potentials using a reference electrode. Now it is possible to obtain STM images of the changing surface structure of electrodes during electrochemical reactions. Much of the early pioneering work in this field was done by Hansma and coworkers [Univ. of Calif. at Santa Barbara (UCSB)].

Uosaki (Hokkaido Univ.) reported on Cu deposition on Pt and Pd electrodes; these electrodes are polycrystalline and initially rough but become much smoother during plating. Itaya (Tohoku Univ.) has done similar studies using single crystal Pt electrodes. Initially, the flame-annealed Pt electrodes have nearly atomically flat surfaces consisting of large (100-nm-wide) terraces joined by monatomic steps. After potential cycling in a weak acid, bumps appear on the terraces; the dependence on experimental variables is being determined. In addition to studying metal electrodes, Itaya and coworkers are obtaining in-situ STM images of semiconductor electrode surfaces. They have imaged the stable hydrogen-terminated Si surface and are beginning to investigate other semiconductor surfaces in aqueous electrolytes, in particular, GaAs and InP. The initial stages of metal (Pt, Au, Ag) electrodeposition on these semiconductor surfaces are also under investigation by Itaya and coworkers. Similar studies of Ge and GaAs electrode surfaces were reported by Nagahara (Arizona State Univ.). Nagahara and coworkers investigated electrodeposition of Ni on Ge(111), which produced smooth films for thicknesses less than five monolayers; for thicker films island growth dominated. They were also able to deposit small (100 nm) Au dots on p-GaAs under the tunneling tip due to the strong electric fields.

Additional STM studies of metal film electrodeposition were reported by Robinson (Bellcore) and Green (Stanford Univ.). Robinson uses an atomically flat graphite substrate and deposits Ag. The deposition is too rapid to follow in real time, but he obtains STM images during the dissolution process. He sees the removal of the film, one monolayer at a time. Green studies underpotential deposition of Pb on Au(111) and is able to obtain real-time images during deposition and removal. The growth occurs preferentially at step edges on the Au surface. After many repeated complete cycles, the Au substrate becomes roughened.

MACROMOLECULES AND BIOLOGY

One of the most exciting potential applications for proximal probes is in the exploration of macromolecular phenomena, especially biomolecules. The slow growth in this direction, evident over the last several years, began to take on much greater dimensions in Oarai, with 23 different groups reporting results in the form of 13 oral and

25 poster papers. Most of the work focused on STM, but a number of other techniques (force microscopy and ion conductance microscopy) are starting to be used.

The variety of molecules being imaged is large. A number of groups chose to work with highly ordered systems in order to immobilize the molecules and to enhance interpretation prospects. Liquid crystalline materials (Smith, IBM Munich) showed good results in several cases, as did three efforts imaging crystallized electroactive organic salts (Fainchtein, Applied Physics Lab (APL)/ John Hopkins Univ. (JHU); Dai, Academia Sinica, Beijing; and Fujita, Univ. of Tokyo). Several other groups (Möller, Univ. of München; Wilson, IBM Almaden; and Ruan, Academia Sinica, Beijing) imaged phthalocyanine molecules adsorbed on metal/ semiconductor surfaces. Very convincing images of the molecules were presented, with the aromatic rings showing the greatest intensity. Wilson (IBM Almaden) related that the use of a Cu substrate was very important since the phthalocyanine molecules reacted with this surface, thereby pinning the molecule. The biological investigations included work on sickle cell anemia hemoglobin (Smith, IBM Munich); phosphatidylcholine bilayers (Bai, Academia Sinica, Beijing; Vidic, Georgetown Univ.); bacteriophage (Bustamante, Univ. of New Mexico); cytoskeletal microtubules (Hameroff, Univ. of Arizona); collagen (Snellman, Univ. of Turku, Finland); polypeptide (McMaster, Agricultural Force Research Council (AFRC), U.K.); and DNA (Selci, Univ. di Roma; Lindsay, Arizona State Univ.; Besenbacher, Univ. of Aarhus, Denmark; Bustamante, Univ. of New Mexico; Gerber, IBM Zurich). One theme that was repeated several times at the meeting was the absolute need for collaboration between polymer/biology and proximal probe experts. Commercial STM instruments are available, but sample preparation and contrast interpretation are nontrivial.

Progress in macromolecule work has been slowed by the problem of developing analytical tools at the same time as one tries to investigate unknown samples. No equivalent Si(111) 7x7 surface is available as a Rosetta stone to guide the macromolecular studies. Miquel Salmeron (Lawrence Livermore) reviewed known sources of trouble: acceptable flat substrates, molecular immobilization, uncertain contrast mechanisms for "insulating" molecules, identification of observed contrast with molecular features (i.e., identification) and, where appropriate, the need to work in situ (i.e., underwater) to prevent dehydration-induced structural changes. His group has worked very hard to exploit the flat, inert surface of graphite, as have many others; he has now concluded that graphite is inappropriate for several reasons and will begin work on other substrates. A number of other substrates are already being tried, including Au grown epitaxially on mica (Lindsay, Arizona State Univ.) and Au grown on Al (Selci, Univ. di Roma).

Several groups showed evidence that mechanical STM tip/molecule interactions were important. Failure to image molecules on graphite was frequently ascribed to skating the molecule across the flat surface under the impetus of the tip. In one case (Blackford, Dalhousie) direct evidence was shown for physical changes to the molecules by the tip. The Dalhousie group has contributed an important new hopping-imaging technique that may reduce or eliminate the problem. They showed that periodic retraction of the tip while scanning could dramatically improve imaging capability and reduce damage. Another approach to eliminate "molecular skating" is to "glue" the molecule in place.

Successful molecular images on graphite were frequently ascribed to adsorption on edges or grain boundaries. One group investigating DNA denatured the molecule to increase its binding sites; others put down glycerol (Hameroff, Univ. of Arizona) or tri 1-Azcridlyral phosphinoxide (TAPO) (Selci, Univ. di Roma) as glue; still others sought to get an ordered overlayer whereby the molecules were trapped in the overlayer.

In addition to the nanoscopic imaging work, several groups investigated the use of proximal probes to characterize more macroscopic (i.e., 10- to 100-nm) structures. Masai (Mitsubishi) described initial efforts to use the STM as a detection mechanism for immunoassay. Both red (Smith, IBM Munich) and white (Hansma, UCSB) blood cells were imaged, the latter by AFM. Hansma also used AFM to capture a sequence of images showing fibrin, reacting under the influence of thrombin, forming into the fibrinogen chains that constitute blood clots. A video tape of the sequence clearly showed the formation of small segments, their eventual attachment into a filament, and then network formation. Contact forces of $< 10^{-8}$ N were essential to acquire this image and, even then, there was evidence for tip-induced molecular displacements. Hansma also demonstrated another proximal probe--the scanning ion conductance microscope--and showed that it could image ion currents through a millipore filter. He is devising ways to improve the technique's lateral resolution (~50 nm) and intends to examine ion channels in biological membranes.

INSTRUMENTS/DEVICES/ APPLICATIONS

There were several presentations on instrumentation. Perhaps the most fascinating was Albrecht et al. (Stanford Univ.), who described microfabrication of STMs in silicon. Using standard photolithographic techniques he built up a three-dimensional scanner using ZnO as the piezoelectric actuator. He claimed the advent of the $10 STM was just around the corner. Application areas exist in parallel operation of STMs, reading data storage, lithography, etc.

In the poster session, Grafström (Univ. of Heidelberg) described some laser-assisted STM experiments in which he used the laser light and STM to characterize the thermal response of substrate and probe tip. This year's conference also presented a number of posters in which STM was combined with other types of instruments such as a coaxial impact-collision ion scattering spectrometer (Nomura, NEC Corp.), a room temperature field ion microscope (Sakurai, Univ. of Tokyo), a transmission electron microscope (TEM) operating in the reflection mode (Nagahara, Arizona State Univ.), a molecular beam epitaxy (MBE) apparatus (Deeken, Univ. of Missouri), an optical microscope (Yasutake, Seiko Instruments), and a VG ESCALAB system (Wiesendanger, Univ. of Basel). Several investigators--Watanabe (Toshiba R&D Center), Lang (Stanford Univ.), and Renner (Univ. of Geneva)--presented results on new variable-, low-, or high-temperature STMs. Shimizu (Fujitsu Labs) designed a new inchworm mechanism for ultra high vacuum (UHV) applications; Huerta Garnica (Instituto Polytecnico Nacionale (IPN), Mexico) designed a long range scanner with a range of 40 x 40 square microns; and Fujii (National Research Lab of Metrology, Japan) designed a new STM scanner from an aluminum alloy. Several researchers--Grafström (Univ. of Heidelberg), He (Academia Sinica, Beijing), and Jan (National Taiwan Univ.)--described new computer control and data acquisition systems.

While the principal excitement in proximal probe development has focused on resolving atomic scale surface features, some investigators are now trying to exploit the tunneling tip as a probe to understand device/engineering surface features. In one elegant experiment, the ballistic electron emission microscopy (BEEM) technique [Bell, Jet Propulsion Lab (JPL)/Calif. Inst. of Tech. (CIT)] was used to show that an AlAs layer capping GaAs was sufficient to prevent hypothesized interdiffusion of Au-Ga and to form a nearly defect free Schottky barrier. The band structure of AlAs was shown not to appear until three monolayers had been deposited. Others examined the potential behavior of pn devices from a cross section (Kordic, Philips Research, Netherlands) and the surface stability of H-passivated silicon (Niwa, Matsushita Electric Ind. Co.). The behavior of field emission cathodes is known to suffer from particulate effects; Niederman (Univ. of Geneva) showed that a tunneling tip could identify specific sites and their emission characteristics. Finally, Smith (IBM Munich) showed that a tunneling tip, used as a displacement sensitive transducer, may improve gravitational wave detection technology by a couple of orders of magnitude. This latter point reinforces earlier work of Colton (Naval Research Lab (NRL), magnetic field detection), Kaiser (JPL/CIT, accelerometer), Quate (Stanford Univ., accelerometer), and Bocho (Rochester, transducer theory) that the tunneling tip may play a major role in detectors.

The very sharp tip of an STM, when operated at higher voltages (10 to 1,000 V) in the field emission regime, can serve as a coherent source of collimated electrons. Saenz (IBM Zurich and Univ. of Madrid) reported on quantum mechanical calculations of these electron beam characteristics. He modeled the source as an array of emitters feeding an electron waveguide followed by a triangular barrier. He found that the angular spread of the emergent beam was independent of the waveguide diameter for most tip geometries. The angular spread is instead determined by the barrier characteristics and is typically 10° to 15° full width. The only exception is for the teton geometry where the predicted angular spread is about one-half as large.

These field emission sources have been used to excellent advantage in electron holography as reported by Tonomura (Hitachi). Electron holography is similar to conventional optical holography except that the hologram is produced by the interference of two electron beams; the reconstruction is by optical techniques. Tonomura previously had used this technique to demonstrate the existence of the Aharonov-Bohm effect. He reported some new results relating to magnetic vortices in type II superconductors. In this recent experiment an electron beam passes by the edge of a superconductor and is deviated by the magnetic field pattern associated with the flux lattice. Reconstruction of the resultant hologram provides an image with sufficient resolution to see individual fluxoids.

FORCE MICROSCOPY (AND OTHER PROXIMAL PROBES)

There was a small session on force microscopy highlighted by the invited talk on "Scanning Probe Microscopy" by Wickramasinghe (IBM Watson), who talked about the current status and future trends in this area, which goes back three decades. After a brief review of the history behind the development of the scanned probe microscopes, he discussed recent developments in the areas of scanning tunneling microscopy, magnetic force microscopy (MFM) (where he has achieved a resolution of 25 nm using Ni tips), electrostatic force microscopy (which was used to measure the voltage gradient between a pn junction), near-field thermal microscopy that uses a microthermal couple as a tip, and near-field acoustic microscopy that uses an acoustic transducer instead of an optical pump to excite an absorber. In the poster session, Williams (IBM Watson) described a capacitive microscope used to image the dopant density in Si. The device has a spatial resolution of 25 nm and is capable of measuring capacitance variations of 10^{-21} F/$\sqrt{Hz}$. Pohl (IBM Zurich) discussed many possible extensions of the STM technique to measure fields, photons, and forces. He was able to use force measurements to distinguish between clean and adsorbate covered surfaces, to perform local optical spectroscopy with unprecedented resolution, and to trace out the borders of semiconductor junctions. Wickramasinghe's talk was complemented by the invited talk given by Hansma (UCSB) in the session on liquid/solid interfaces. Hansma focused on imaging liquid-solid interfaces such as electrodes and biological molecules with scanning probe microscopes. (The designs of the scanning probe microscopes were discussed in a separate poster paper by Drake of UCSB.)

There were two other talks and several posters given on various aspects of force microscopy. Terris (IBM Almaden) talked about charge imaging and contact charging (tribocharging) using a force microscope. He developed a method to image localized charge on insulating surfaces in which charge and topography can be distinguished and the sign of the charge determined. The method uses an oscillating tip and an electrode behind the sample to measure the force gradient. By touching a Ni tip to the surface of polymethyl methyl methacrylate (PMMA), he recorded the first observation of bipolar charge transfer in a single tribocharging event. Colton (NRL) presented a poster on measuring the nanomechanical properties--elasticity and hardness--by using the AFM as a nanoindenter. He also was able to measure the surface forces--both attractive and adhesive forces--associated with various surfaces, including monolayer films deposited on metal surfaces. Baratoff (IBM Zurich) presented a poster on the atomic scale electronic and mechanical interaction effects in STM and AFM. Baratoff's group used ab-initio calculations to correlate atomic scale tip-sample forces with tip-induced changes in electronic structure for graphite(001) and Al(111) surfaces. Nagahara (Arizona State Univ.) investigated the effects of strain caused by tunneling. He found that reversible elastic strain accompanies tunneling (without plastic flow) for a W tip on InP. The tunneling gap size and tip shape could be observed directly during tunneling. The strain was measured with a TEM through the electron beam Bragg diffraction contrast mechanism. Uozumi

(Aoyama Gakuin Univ.) detected mechanical contact of the tip to the surface by an ultrasonic pulse-echo method. Grütter (Univ. of Basel) talked about high resolution MFM of periodic and nonperiodic magnetic structures. The resolution was found to be tip and sample dependent. A resolution as high as 10 nm was found for FeNdB. Hartman (KFA-Jülich) presented a theory of MFM that analyzed the mechanisms responsible for contrast formation in MFM.

Most of the other posters focused on the design of new AFMs or their application. For example, Albrecht (Stanford Univ.) presented a poster on the microfabrication of thin film SiO_2 and Si_3N_4 cantilevers with integrated tips for AFM. Erlandsson (Univ. of Linköping) built a long scan range AFM that uses a fiber-based laser interferometer as the force sensor. Alvarado (IBM Zurich) developed an MFM using a polarizing interferometer to measure the deflection of GaAs or Si cantilevers with a small ferromagnetic tip attached; lateral resolution down to 30 nm was measured. Sarid (Univ. of Arizona) used a laser diode to illuminate a vibrating tip as a way to measure force gradients. Göddenhenrich (KFA-Jülich) built an AFM using capacitive displacement detection. Schmidt (Johann Wolfgang Goethe Univ.) constructed cantilever force sensors from carbon and glass fibers. Ishizaka (Tohoku Univ.) imaged the surfaces of metal oxides in air with the AFM. Barrett (Stanford Univ.) used an optical deflection-sensed AFM that also uses microfabricated cantilevers to examine atomic steps of a polished sapphire surface. He was also able to image the accumulation of charge on surfaces (with the same periodicity as the step) by applying a bias to the back side of the sample. Yamada (National Research Lab of Metrology, Japan) studied layered compounds--BN and mica; Heinzelmann (Univ. of Basel) used AFM to study thin films of hydrogenated amorphous carbon coating on magnetic recording media and AgBr single crystals; and Bryant (Univ. of Missouri) imaged purple membranes. Wadas (Univ. of Basel) analyzed magnetic bit patterns taking into account the magnetic and van der Waals interactions between the tip and sample. Iizuka (Alps Electric Co.) built a combined MFM and scanning electron microscope (SEM) in order to resolve important questions concerning the relationship between measured force and domain distribution and the influence of stray fields associated with the tip.

LITHOGRAPHY

There were six posters and one talk dedicated to patterning with the STM. However, several other presentations showed patterning results unrelated to their main topic. Alex deLozanne (Univ. of Texas) gave the talk and devoted part of it to an overview of patterning efforts with the STM both at STM '89 and in the literature. Various techniques were described. Several people reported e-beam drilling 3-nm holes into graphite (e.g., Albrecht et al., Stanford Univ.; Rabe et al., Max-Planck, FRG; Thomson et al., Manitoba Univ., Canada). This works in air and it appears that water vapor is the critical atmospheric ingredient. Dijkkamp et al. (Philips Research, Netherlands) created somewhat larger features in silicon by crashing the tip mechanically into a silicon surface. Surprisingly this seemed a repeatable process! Marrian (NRL) presented the only results on lithography with an actual resist and went rather further than others by quantifying exposure thresholds, resolution limits, and energy dependence of the feature size. At the University of Texas, deLozanne has deposited features from organo-metallics and WF_6. Feature sizes down to 10 nm and a threshold of 15 V were claimed. Interestingly with WF_6, both etching and deposition were observed on Si<111>. The determining factor seemed to be the sample temperature, 50 °C being the threshold. Similar results have been reported in the literature by McCord et al. (IBM Yorktown Heights). One would expect that this is an area where interest will grow in the future.

Several presentations on silicon had relevance to microfabrication in that they studied the oxidation of silicon following various oxide stripping and surface passivation steps. Some impressive passivation times were claimed of up to 60 hours in air (Niwa, Matsushita, Japan). Nakagawa (Toray R.C., Japan) observed atomic resolution in air for several hours. However, most authors acknowledged that oxidation rates and resolution degradation increased significantly under the action of the tunnel current.

SUMMARY

It is clear that the STM is becoming an accepted surface analysis instrument. Results, particularly in the semiconductor field, were presented that displayed short range atomic order not visible with other surface analytical techniques. In fact, some of these studies belonged in a mainstream surface physics conference. On the other hand, there was a tremendous amount of work presented that consisted of attempts (usually only partially successful) to image a complex material or system. In only a very few cases outside the semiconductor area (D. Smith, IBM Munich, for example) were the STM results of sufficient quality to be analyzed to provide insights into the fundamental physics, chemistry, or biology of the system being studied. Nevertheless, clear progress was evident in these important efforts to broaden the scope of proximal probe impact.

The proceedings of this conference are to be published in the *Journal of Vacuum Science and Technology* early in 1990.

Richard G. Brandt is in the Physics Division at the Office of Naval Research (ONR), where he is manager of the Surface Physics Program. He has also managed programs in the areas of superconductivity, electromagnetism, and ionospheric physics. Dr. Brandt received his degree at Yale University and was employed at General Research Corporation prior to joining ONR in 1968.

Richard J. Colton is a supervisory research chemist and head of the Advanced Surface Spectroscopy Section at NRL. He earned his B.S. and Ph.D. degrees from the University of Pittsburgh in 1972 and 1976, respectively. He performed his graduate work under the direction of Professor J.W. Rabalais in the areas of ultraviolet and x-ray photoelectron spectroscopy. In 1976, he was awarded a National Research Council Resident Research Associateship at NRL for a research proposal dealing with secondary ion mass spectrometry (SIMS). Dr. Colton joined the staff at NRL in 1977 and conducts basic and applied research in the area of surface chemistry. His research interests include surface and materials analysis by electron spectroscopy and SIMS, the development of new surface analytical techniques, the study of the mechanisms of molecular and polyatomic ion emission and, most recently, the study of surfaces and molecular adsorbates by scanning tunneling microscopy, the measurement of the nanomechanical and surface forces properties of materials using atomic force microscopy, and the development of new sensor concepts using electron tunneling. Dr. Colton is a member of the ACS, ASTM, Sigma Xi, and AVS. He is first vice chairman of the ASTM E-42 Committee on Surface Analysis and was a former chairman of the AVS Applied Surface Science Division. Dr. Colton is also a member of the editorial boards of Surface and Interface Analysis and Applied Surface Science.

C.R.K. Marrian received a B.A. degree in engineering and a Ph.D. degree in electrical engineering in 1973 and 1978, respectively, from Cambridge University, England. He subsequently spent nearly 3 years at C.E.R.N. in Switzerland working on a detector for a quark search experiment. In 1980 Dr. Marrian joined the Surface Physics Branch at NRL. At NRL he has continued his studies of high current density thermionic emitters, particularly under conditions of nonideal vacuum. More recently he has developed research interests in the limits of lithographic techniques in the field of microfabrication. To this end he has used the low energy electron beam available in an STM-type configuration to study the electron-material interactions in e-beam lithography. Dr. Marrian is further involved in research into architectures and algorithms for electronic implementations of artificial neural networks.

James S. Murday received a B.S. in physics from Case Western Reserve in 1964 and a Ph.D. in solid state physics from Cornell University in 1970. He is superintendent of the Chemistry Division at NRL and advisor to the Surface/Interface Physics Program at ONR. His research interests include interface analysis; surface modification technology; surface reaction kinetics; chemistry of electronics materials; and application of surface science to contamination control, corrosion, tribology, and chemical microsensors. Dr. Murday is a member of the APS, ACS, AVS, and MRS. In the AVS he has served as chairman of the Local Arrangements Committee for the 1982 and 1986 National Symposia, trustee for 1981-1984, director for 1986-1988, and member of the AIP Governing Board for 1986-1989.

Joseph A. Stroscio is a research chemist at NIST. He earned a B.S. (highest distinction) in physics from the University of Rhode Island in 1978 and a Ph.D. in physics from Cornell University in 1986. He performed his graduate research work under the direction of Professor W. Ho in the area of surface physics. In 1985, he was awarded a Postdoctoral Research Associateship at the IBM T.J. Watson Research Center, where he performed research in scanning tunneling microscopy. His research interests include interface analysis, surface modification technology, and the development of new surface analytical techniques. Dr. Stroscio is a member of AAAS, APS, AVS, and MRS.

NEW MOLECULAR MATERIALS

Neal R. Armstrong

One of the most rapidly expanding areas of chemistry is molecular materials. This is an area in Japan where coordination between national needs, industrial development, and university research is well articulated and where the Japanese feel that they are competitive in the international arena. This article summarizes the papers presented at the 40th meeting of the International Society of Electrochemistry and briefly describes research in new molecular materials at Riken, laboratories at the Yokohama campus of the Tokyo Institute of Technology, and the University of Tokyo.

INTRODUCTION

This article summarizes findings and impressions from a 2-week visit to Japan, 14-27 September 1989, to attend the 40th meeting of the International Society of Electrochemistry (ISE), held in Kyoto. Pre- and post-ISE conferences were held at Tohoku University in Sendai and the Tokyo Institute of Technology, respectively. Significantly, the Japanese did not speak at these pre- or postconferences. There was a one-way transmittal of information. Details of scientific efforts were only available from private conversations. In addition to these conferences, visits to Riken, laboratories at the new Yokohama campus of the Tokyo Institute of Technology, and the University of Tokyo are briefly described.

While the focus of this article could logically extend across a number of scientific areas impacted by electrochemistry, it is most sensible to narrow the discussion to one area, *new molecular materials*. This choice is consistent with the focus of a large segment of research funding in the United States, Japan, and Europe, but additionally, it is an area *very* strongly impacted by electrochemistry and electrochemists. It also appears that this is an area in Japan where coordination between national needs, industrial development, and university research is well articulated. In general, the Japanese feel that they are competitive in the international arena in this area, in sharp contrast to the area of biotechnology and chemistries of the life sciences, where they feel that they are woefully behind the United States and Europe. Only a few papers are described here primarily because much of what was presented was not new and not particularly competitive on the international scene. I chose instead to focus on those papers representing areas where the Japanese are extremely competitive and where there is some sense of coordination with emerging technologies in the research. This does not necessarily mean that there was no new science presented, which is being done without a view to emerging technologies--it simply reflects my own set of interests in the Japanese system at the present time.

NEW MOLECULAR MATERIALS

The area of molecular materials, e.g., polymers or other condensed-phase media, where the resultant material retains many of the properties of the isolated monomer subunits, is one of the most rapidly expanding areas of chemistry today. This area is driven by several potential new technologies, or technologies in place, for which significant improvements are sought, many of which were touched on during this visit, including:

- Biomimetic photosynthetic assemblies
- Photographic or electrophotographic sensitizers
- Electrochromic display materials
- Chemical sensors (for both gas-phase and solution-phase analyses)
- Electrooptic and related devices predicated upon the nonlinear optical responses of organic materials
- Optical data storage materials (based upon phase changes, isomerization, electron transfer, etc.)

DISCUSSION OF PAPERS PRESENTED AT THE ISE MEETING

The electrochemical growth of conductive and near conductive polymers is now a mature area, where a number of phenyl-based and heterocycle-based systems have been grown and characterized on a variety of electrode surfaces and in a variety of electrolytes. It is generally agreed that the challenge in this area now is to obtain more highly organized versions of these thin films to take advantage of the potentially highly directional nature of (1) electrical or ionic conductivity and (2) optical or electro-optical properties.

At the ISE conference, several different approaches to this problem were introduced. An especially intriguing approach championed by the research group of Professors T. Shimidzu and K. Honda (Kyoto University) involves the use of Langmuir-Blodgett (LB) layers of polymerizable pyrroles ("Conducting Polymer Thin Films Prepared by LB Technique and Electrochemical Polymerization," by M. Ando, Y. Watanabe, T. Iyoda, K. Honda, and T. Shimidzu; and "Electrochemical Control of Layered Structure of Conducting Polymer Composite Film," by T. Iyoda, H. Toyoda, K. Honda, and T. Shimidzu). Three methods were discussed involving (1) LB fabrication of multilayers of the organized assembly followed by polymerization and doping, (2) LB fabrication with simultaneous polymerization (reactions occurring while the LB film is withdrawn on the electrode substrate), and (3) polymerization followed by LB film formation on the electrode surface. All of these approaches allow the systematic integration of different polymerized LB structures in a bilayer or multilayer format. The intent is to achieve thin film arrays with a specific electrochromic (display technology) property or a diode-like electronic rectification that can be achieved by interfacing two molecular materials with widely differing electron affinities. In this last area, it is extremely important to achieve sharp interfaces between each layer, and the LB/polymerization procedures offer considerable promise that such precision may be achieved on molecular dimensions.

Several potentially interesting nonlinear optical (NLO) materials can be achieved by this approach, a technology already in place in several U.S. and Japanese laboratories--but with LB films only (minus the polymerization steps) or with polymerization achieved by absorption of ultraviolet (UV) light. In addition, the electroluminescent (EL) molecular diodes referred to later in this article may be vastly improved in their operating characteristics by achieving the sharp interfaces this technology affords. Recombination of electrons and holes at the p-n diode interface results in light emission in the visible, tunable over a wide wavelength region. Lowering the necessary applied voltage and/or currents, as well as achieving better device stability,will depend upon interface quality--and this quality may be vastly improved by the LB methods discussed here. Adapting this approach to these other technologies will require production of electropolymerizable amphiphiles with substituents of interest for EL-diode or NLO applications. These Japanese investigators seem to be well aware of these needs, and we can anticipate further interesting developments from this group.

The deposition of organic materials as thin films is often limited by their incompatibility with either vacuum deposition, polymerization of a cast film, or LB techniques. An interesting alternative has now been developed that calls for solubilization of either the *monomeric molecule* or even *small particles* in aqueous micelles that contain a ferrocene moiety capable of undergoing electrochemical oxidation and/or other groups capable of undergoing electrical reaction. The papers presented by T. Saji ("Formation of Pigment Thin Films by Electrolysis of Surfactants With Ferrocenyl Moiety," by T. Saji, Y. Ishii, and M. Goto; and "Electrochemical Preparation of Phthalocyanine Layers on an Al Substrate Using Aqueous Surfactant Solutions," by K. Hoshino, S. Yokoyama, T. Saji, and H. Kokado) described this micellar disruption method that has been developed for phthalocyanines and perylenes but that may be applied to a wide range of materials.

The process of micelle formation may require optimization for each type of molecular material; the question of whether individual monomers, small aggregates, or small particles can be formed in stable micelle solutions is under active investigation for a wide range of materials. Constant potential electrolysis of the stabilized solutions (e.g., oxidation of the ferrocene) destroys the micelle temporarily at the electrode surface and causes release of the pigment material, accompanied by the probable destruction of the electroactive material. Compact, thick, or thin films were demonstrated, with high optical quality (transmission) apparent. The prospect of alternating electrolysis in two or more micelle solutions, which may be used to create bilayer or multilayer thin films from molecular materials with widely differing electron affinities (possible EL-diode, photodetector, and NLO applications), was also demonstrated.

The paper on "Electroluminescence in Organic Dye Films," by T. Tsutsui, C. Adachi, and S. Saito, is notable primarily because of the fashion in which it dovetails with some of the previous topics and demonstrates how an electrochemical meeting might be an appropriate venue for the presentation of research that need not have appreciable electrochemical character. In both the United States and Japan, there is considerable development work in progress devoted to a new class of display device technology based upon electroluminescence at an interface between two dissimilar molecular semiconductors (pigments like perylenes and charge-transport materials like phenyl-substituted amines). Rapid electron-hole pair recombinations at the interface between these two materials, preceded by charge injection from an indium tin oxide anode and a MgAg alloy cathode, result in high light output over a spectral range determined largely by the fluorescence spectrum of the pigment. Challenges remaining in this area include attainment of lower operating voltages and currents, wider spectral ranges for emission, and improved device stability under continuous operating conditions. The authors of this paper represent only one of a number of university and industrial groups addressing all of the issues described above. They are all chasing a group at Kodak in the United States that has recently reported the best operating efficiency to date.

This paper suggests that improvements are being rapidly made and that this technology is probably close to commercialization. The real challenge now will be to determine if a multilayer technology will be realizable, with emitting layer dimensions of 50 to 100 Å and with gain producing mirrors situated at two ends of the multilayer array (a pseudo-GaAs/GaAlAs quantum well laser). Although not specifically addressed at this conference, this issue is on the minds of several investigators in Japan. Realization of such a technology will require better control of molecular deposition than is now routinely available.

The question of control of two dimensionality in a polymer thin film has been addressed ("Electropolymerization of a Vacuum-Evaporated Monomer Film," by A. Yasuda and J. Seto) by workers at Sony, by vacuum depositing the monomer first (which allows patterning down to the ~1-micron level--dimensions could be narrowed with subsequent e-beam lithography) into a conductive substrate, followed by electropolymerization. In addition to allowing patterning, this approach may allow for electropolymerization of a wider array of materials, including many that are only sparingly soluble in any solvent but are vacuum compatible. The challenge in this area will be to determine the effect of chain length propagation on the physical and electrical properties of the resultant polymers.

The two presentations by Fujihira ("Artificial Visual System by LB Film Modified Electrode," by K. Nishiyama and M. Fujihira; and "Artificial Photosynthetic Reaction Center Constructed With Monolayer Assembly," by M. Fujihira, T. Kamei, and M. Sakomura) summarize the interesting contributions of the Fujihira group in the area of LB films, interfaced to electrodes to mimic the vectoral electron transfer inherent to photosynthesis at the molecular level and to mimic the photochemically induced "switching" phenomenon inherent in visual systems at the molecular level.

In the mimetic visual system, amphiphilic spiropyran (SP) derivatives are laid down on an electrode surface, and evidence for a change in permeability to an electroactive ion, induced by photochemical isomerization of the SP derivative, is probed by measuring the electron transfer rates of a probe molecule such as ferri/ferrocyanide. Clear "on" and "off" states ought to produce substantial differences in electron transfer rates of the probe. Differences are seen, but the contrast between "on" and "off" states is subtle, due in part to the inherent permeability of the LB layers through defect sites, pinholes, etc. Further development and improvement of this technology would appear to provide potential for photochemical switching elements, addressable at extremely small lateral dimensions.

FUJIHIRA LABORATORIES AT YOKOHAMA

This group is quite well funded, has kept current in most of the recent synthetic and LB related technologies, and is aware of most of the important developments in the areas described above and of the direction this area of molecular materials is taking on the international scene. Fujihira recently became the department head of the new Department of Biomolecular Engineering, which will result in a new building over the next several years, a new faculty, and a new curriculum. Industrial sponsors contribute substantially to the support of almost all of Fujihira's students. The decision to support these students is apparently made as a result of a competitive examination process at the beginning of their graduate careers and insures the students of employment in that industry upon graduation.

FRONTIER RESEARCH PROGRAM AT RIKEN

I visited Drs. Hara and Sasabe of the Frontier Research Program (FRP) at Riken. Although little of the ongoing research there is related directly to electrochemical phenomena, it is related to the development of new materials. Although I was shown around the FRP projects involving new molecular materials and bioelectronic materials, most of my attention was focused on the new materials program, and even more specifically on the organic molecular beam epitaxy (OMBE) system that has been constructed. The system includes the appropriately modified Knudsen cells to accommodate deposition of low vapor pressure organics, such as phthalocyanines, as well as those of higher vapor pressure, requiring temperatures well below room temperature to keep the deposition under control. A multibeam system has been created that will ultimately allow the preparation of exotic new multilayer materials, with ordering competitive with the LB approaches to thin film creation mentioned earlier. Characterization of thin film growth is presently carried out by a combination of electron spectroscopies, reflection high energy electron diffraction, and a scanning tunneling microscope soon to be attached to the ultrahighviolet (UHV) chamber.

This system is presently unique in the world, in that it has provided the first examples of epitaxial growth of a large organic molecule (such as phthalocyanines) on a low dimensional solid substrate, the metal dichalcogenide MoS_2.* This work is significant in that it represents a potential breakthrough in the growth of single crystal thin films of vacuum compatible organic solids, such that oriented materials can be studied for several of the applications mentioned above. Its most interesting application may be for nonlinear optical systems, where there is a need to characterize both the second and third order susceptibilities of highly ordered organic materials.

There is now an impressive array of optical characterization techniques in place at the FRP at Riken, including third harmonic generation, femtosecond lifetime and saturable absorbance studies, and related techniques necessary to characterize these highly organized layers, once produced. The total dollar amount committed to personnel and equipment for the study of new materials at Riken is impressive (at least $5M in equipment alone) and is strongly coordinated with the other FRP program in biomolecular materials.

*M. Hara et al., *Jpn. J. Appl. Phys.* 28, L306 (1989).

THE RESEARCH OF PROFESSORS KOMA AND KOBAYASHI AT THE UNIVERSITY OF TOKYO

There appears to be strong coordination between the efforts of the FRP group at Riken and the research of Professors Koma (van der Waals epitaxy) and Kobayashi (nonlinear optical processes) at the University of Tokyo. Following my visit to Riken, I spent some time in the laboratories of Professor Koma and discovered a complementary effort in epitaxial growth of phthalocyanines on low dimensional solid surfaces ($PbPc/MoS_2$). This work grows out of his considerable efforts in the characterization of epitaxial growth of metal dichalcogenides on other single crystal solid substrates, an area of potentially great importance. Because of the difficulty of preparing these dichalcogenide materials in the past, their semiconductor>>metallic and nonlinear optical properties have not been fully appreciated, along with the possibilities they provide as substrates for the growth of other electronic materials. Koma's approach to growing these systems in UHV with MBE technologies may mean that large area thin films of these very unreactive solids may be made readily available, with chemical and physical properties that can be "tuned" over a wide range and with surfaces that make them attractive as interfaces for other molecular materials.

OVERALL IMPRESSIONS

It seems that the Japanese have taken the area of "molecular materials" more seriously than in the United States to the extent that their efforts are more focused and coordinated than those in this country. This should not be surprising by now, given their track record in related areas. There seems to be a greater sensitivity to the long term technological applications of this area at the university level than one would expect to find in the United States--and one could argue that this has a negative side effect of keeping the research too focused, so that new opportunities may be missed that investigators in other countries will seize on. On the other hand, the Japanese are producing a generation of scientists with the skills necessary to manipulate molecules on exacting scales, and they will be well poised to exploit those people when technologies such as all optical computing and optical data storage at the molecular scale come closer to realization.

Neal R. Armstrong, presently head of the Department of Chemistry at the University of Arizona, received his Ph.D. degree in analytical chemistry from the University of New Mexico in 1974, as a result of research conducted in the solid state physics group at Sandia National Laboratories. Following a postdoctoral fellowship at Ohio State University, he joined the faculty at Michigan State University in 1975 and then moved to the faculty at the University of Arizona in 1978. Trained initially as an electrochemist, his research interests now include the interfacial and surface chemistries of molecular electronic materials, active metals, and low dimensional solids. Technologies developed and/or in use in his group for these studies include electrochemistry, photoelectrochemistry, interdigitated microcircuit measurements of dark and photoelectrical properties, microgravimetric techniques, optical waveguide studies of surface adsorbates, quantitative surface electron spectroscopies, surface vibrational spectroscopies, and scanning tunneling microscopy. Professor Armstrong is also a member of a larger consortium of scientists at the University of Arizona interested in materials for all optical signal processing and optical data storage.

INTERNATIONAL MEETINGS IN THE FAR EAST
1990-1995

Compiled by Yuko Ushino

The Japan Convention Bureau, the Science Council of Japan, and journals of professional societies are the primary sources for this list. Readers are asked to notify us of any upcoming international meetings and exhibitions in the Far East which have not yet been included in this report.

1990

Date	Title/Attendance*	Site	Contact for Information
March 1	Workshop on Advanced Motion Control	Yokonama, Japan	Professor Kohei Ohnishi Department of Electric Engineering Keio University 3-14-1 Hiyoshi Kohoku, Yokohama 223
March 1-7	PLASTINDIA '90 International Exhibition and Congress for Plastic Industry	New Delhi, India	Mr. Schuld or Mr. Wiemann NOWEA, FRG
March 5-9	The 6th Asian-Pacific Conference on Nondestructive Testing (APCNDT)	Blenheim, New Zealand	Conference Secretariat 6th Asian-Pacific Conference on Nondestructive Testing P.O. Box 199 Blenheim, New Zealand
March 12-14	International Forum on Fine Ceramics '90 10-F100-J900	Nagoya, Japan	Japan Fine Ceramics Center 2-4-1 Mutsuno Atsuta-ku, Nagoya 456
March 12-16	International Conference on Supercomputing in Nuclear Applications	Mito, Japan	Kiyoshi Asai Conference Secretariat Computing Center, JAERI Tokai-mura, Naka-gun Ibaraki 319-11
March 14-17	Mining and Mineral Processing Exhibition and Conference	Jakarta, Indonesia	Reed Exhibition Companies 26 The Quadrant Richmond upon Thames, Surrey TW9 2 DL, UK
March 15-17	International Bio Symposium 90 Nagoya "BIOTECHNOLOGY/ Today & Tomorrow" 10-F50-J350	Nagoya, Japan	International Bio Symposium 90 Organizing Committee c/o Chubu Bioindustry Promotion Council 2-17-22 Sakae Naka-ku, Nagoya 460
March 19-20	Symposium on HTGR Technologies Design, Licensing Requirements and Supporting Technologies	Tokyo, Japan	Shinzo Saito 3607 Niihori, Narita-cho Oharai-machi, Ibaraki 313-13

*Note: Data format was taken from the Japan International Congress Calendar published by the Japan Convention Bureau.

No. of participating countries
F: No. of overseas participants
J: No. of Japanese participants

1990			
Date	**Title/Attendance**	**Site**	**Contact for Information**
March 22-23	U.S. Japan High-Tech Development Strategy Seminar	Tokyo, Japan	Advisor for the Policy Study Group Toshio Nishizawa, Nishizawa & Associates Shibuya Homes 423 2-1 Udagawa-cho Shibuya-ku, Tokyo 150
March 22-24	Kyoto Bioscience Symposia VI "Role and Regulation of Heart Shock Response" N.A.-F12-J50	Kyoto, Japan	Institute for Virus Research Kyoto University 53 Shogoin-Kawahara-cho Sakyo-ku, Kyoto 606
March 29-31	IEEE International Workshop on Advanced Motion Control 10-F30-J70	Yokohama, Japan	Dr. K. Ohnishi Department of Electrical Engineering Faculty of Science and Technology Keio University 3-14-1 Hiyoshi, Kohoku-ku Yokohama-shi, Kanagawa 223
April 1-6	The 1990 National Engineering Conference of the Institution of Engineers Australia	Canberra, Australia	The Conference Manager 1990 National Engineers Conference The Institution of Engineers 11 National Circuit Barton, ACT 2600
April 2-6	IEE-Japan/1990 International Power Electronics Conference-Tokyo, IPEC-Tokyo'90	Tokyo, Japan	Secretariat The Institute of Electrical Engineers of Japan 1-12-1 Yuraku-cho Chiyoda-ku, Tokyo 100
April 4-6	The 2nd International Symposium on Power Semiconductor Devices & JCs (ISPSD '90)	Tokyo, Japan	Yoshiyuki Uchida Fuji Electric Co., Ltd. Matsumoto Factory 2666 Tsukama, Matsumoto Nagano 390
April 8-12	1990 International Topical Meeting on Optical Computing 10-F100-J300	Kobe, Japan	OC'90 Secretariat Business Center for Academic Societies Japan (BCASJ) 3-23-1 Hongo Bunkyo-ku, Tokyo 113
April 12-14	1990 International Topical Meeting on Photonic Switching	Kobe, Japan	PS'90 Secretariat Business Center for Academic Societies Japan (BCASJ) 3-23-1 Hongo Bunkyo-ku, Tokyo 113
April 13-16	The 25th Yamada Conference on Magnetic Phase Transition (MPT '90) 10-F100-J200	Osaka, Japan	MPT '90 Secretariat Professor Y. Miyako Faculty of Science Hokkaido University Nishi 8-chome, Kita 10-jo Kita-ku, Sapporo 060
April 17-19	The 5th International Symposium on "Advanced Technology in Welding and Materials Processing and Evaluation"	Tokyo, Japan	Japan Welding Society 1-11 Kanda Sakuma-cho Chiyoda-ku, Tokyo 101
April 22-25	Asia-Pacific Biochemistry Engineering Conference '90 (APBioChEC'90)	Kyungju, Korea	APBioChEC'90 Secretariat c/o Professor Ho Nam Chang Department of Chemical Engineering Korea Adv. Inst. of Sci. & Technol. P.O. Box 150, Cheongryang Seoul 130-650, Korea

Date	Title/Attendance	Site	Contact for Information
April 23-25	The 3rd Japan-China Joint Conference on Fluid Machinery 8-F60-J100	Osaka, Japan	Professor Yutaka Miyake Department of Mechanical Engineering Faculty of Engineering Osaka University 2-1 Yamada-Oka Suita, Osaka 565
April 23-26	International Cryogenic Engineering Conference	Beijing, People's Republic of China	Professor C.S. Hong Cryogenic Laboratory Academia Sinica P.O. Box 2711, Beijing 10080
April 23-27	Nankai Conference: International Conference on Physics Education Through Experiments	Tianjin, People's Republic of China	Professor Zhao Jing-yuan Department of Physics Nankai University Jianjin
May (tentative)	SEAISI Conference: Recent Developments and Applications of Hot Cold Rolled and Coated Products	Kaohsiung, Taiwan	South East Asia Iron and Steel Institute P.O. Box 7759 Airmail Distribution Center NAIA, Pasay City 1300, Philippines
May 2-4	1st World Congress on Biosensors	Hong Kong	Penny Moon, Conference Manager Elsevier Seminars Mayfield House 256 Banbury Rd. Oxford OX2 7DH, U.K.
May 7-11	Pacific Rim Congress: Geology Structure, Mineralization and Economics of the Pacific Rim	Gold Coast, Australia	Australasian Institute of Mining and Metallurgy P.O. Box 731 Toowong, QLD 4066 Australia
May 14-18	The 14th World Mining Congress and Exhibition	Beijing, People's Republic of China	14th World Mining Congress 54 Sanlihe Road Beijing
May 17-19	1990 Yukawa International Seminar "Common Trends in Mathematics and Quantum Field Theories" (Seminar)	Kyoto, Japan	Secretariat 1990 Research Institute for Fundamental Physics (RIFP) Kyoto University Oiwake-cho, Kitashirakawa Sakyo-ku, Kyoto 606
May 19-26	The 27th International Navigation Congress 62-F500-J500	Osaka, Japan	Japan Organizing Committee for 27th International Navigation Congress of PIANC c/o Port and Harbor Bureau City of Osaka 2-8-24 Chikko Minato-ku, Osaka 552
May 20-25	The 9th International Symposium on Carotenoids	Kyoto, Japan	Professor Masayoshi Ito Kobe Women's College of Pharmacy 4-19-1 Motoyamakita-Machi Higashinada-ku, Kobe 658
May 20-25	The 17th International Symposium on Space Technology and Science	Tokyo, Japan	Ms. Hiroko Sakurai 17th ISTS Secretariat c/o Institute of Space and Astronautical Science 3-1-1 Yoshinodai Sagamihara, Kanagawa 229

1990			
Date	**Title/Attendance**	**Site**	**Contact for Information**
May 20-26	The 27th Congress of Permanent International Association of Navigation Congress (PIANC) 70-F500-J500	Osaka, Japan	Secretariat Japan Organizing Committee for 27th Congress of PIANC c/o Port & Harbor Bureau, City of Osaka 2-8-24 Chikko Minato-ku, Osaka 552
May 21-22	Conference and Exhibition: Foundry Asia '90	Hong Kong	FMJ International Publications
May 21-23	4th Symposium on Our Environment	Singapore	Wong Ming Keong Dept. of Chemistry National University of Singapore Singapore 0511
May 29-June 1	The International Conference on Manufacturing Systems and Environment - Looking Forward to the 21st Century	Tokyo, Japan	T. Nakajima The Japan Society of Mechanical Engineers Sanshin Hokusei Building 2-4-9 Yoyogi Shibuya-ku, Tokyo 151
June (tentative)	The 10th International Conference on Vacuum Metallurgy	Beijing, People's Republic of China	The Chinese Society of Metals 46 Dongsixi Dajie, Beijing 100711
June 4-7	Joint International Conference on Marine Simulation and Ship Maneuverability (MARSIM & ICSM 90) N.A.-F130-J120	Tokyo, Japan	Secretariat: MARSIM & ICSM 90 c/o ISS International, Inc. 5F, Shinkawa Building 2-2-21 Shiba-koen Minato-ku, Tokyo 105
June 5-8	International Symposium on Reliability and Maintainability (ISRM 1990-Tokyo) 20-F200-J400	Tokyo, Japan	Union of Japanese Scientists and Engineers (JUSE) 5-10-11 Sendagaya Shibuya-ku, Tokyo 151
June 11-15	1990 International Conference: Metallurgical Coatings	Beijing, People's Republic of China	Chinese Society of Metals 46 Dongsixi Dajie, Beijing 100711
June 11-15	1990 International Conference: Special Melting	Beijing, People's Republic of China	Chinese Society of Metals 46 Dongsixi Dajie, Beijing 100711
June 15-20	The 2nd International Conference: Aluminum Alloys - Physical and Mechanical Properties	Beijing, People's Republic of China	Beijing University of Aeronautics and Astronautics Beijing 100083
June 19-21	The 1990 Coal Handling and Utilization Conference	Sydney, Australia	The Conference Manager Coal Handling and Utilisation Conference 1990 The Institution of Engineers, Australia 11 National Circuit Barton, ACT 2600
June 22-26	International Conference on Dynamics, Vibration, and Control	Beijing, People's Republic of China	Professor Wei Jinduo Chinese Society of Theoretical and Applied Mechanics No. 15 Zhong Guancun Street Beijing

1990			
Date	**Title/Attendance**	**Site**	**Contact for Information**
June 24-27	The 5th Japan-U.S. Conference on Composite Materials	Tokyo, Japan	Professor Akira Kobayashi Department of Materials Science Faculty of Engineering University of Tokyo 7-3-1 Hongo Bunkyo-ku, Tokyo 113
June 26-30	International Symposium on High Temperature Corrosion and Protection	Shenyang, People's Republic of China	Professor Man Yongfa Institute of Metal Research Academia Sinica 2-6 Wenhua Road Shenyang, Liaoning Province
June 27-29	International Symposium on Chemistry of Microporous Crystals (CMPC)	Tokyo, Japan	Professor Tomoyuki Inui Secretary, CMPC Department of Hydrocarbon Chemistry Faculty of Engineering Kyoto University Kyoto 606
July 1-5	The 1st Tokyo Conference on Advanced Catalytic Science and Technology (TOCAT 1) 20-F100-J200	Tokyo, Japan	Secretariat: TOCAT 1 c/o Department of Synthetic Chemistry Faculty of Engineering Tokyo University 7-3-1 Hongo Bunkyo-ku, Tokyo 113
July 1-6	The 3rd International Conference on Technology of Plasticity (3rd ICTP) 10-F300-J700	Kyoto, Japan	The Organizing Committee 3rd ICTP c/o The Japan Society for Technology of Plasticity Torikatsu Building 5-2-5 Roppongi Minato-ku, Tokyo 106
July 2-6	The 26th Yamada Conference "Surface as a New Material"	Toyonaka, Osaka, Japan	Professor A. Okiji Secretariat of YCS'90 Department of Applied Physics Osaka University 2-1 Yamadaoka, Suita 565
July 5-6	IEEE International Workshop on Intelligent Robots and Systems '90 (IROS'90)-Towards a New Frontier of Applications	Tsuchiura, Japan	Mr. Masakatsu Fujie IROS'90 Mechanical Engineering Research Laboratory Hitachi, Ltd. 502 Kandatsu-machi Tsuchiura-shi, Ibaraki-ken 300
July 6-7	The 1st KSME-JSME Fracture and Strength Conference (Fracture and Strength '90)	Seoul, Korea	Professor Hideaki Takahashi Research Institute for Strength and Fracture of Materials Tohoku University Aoba Tsurumaki Aza Sendai 980
July 9-11	Japan-U.S.A. Symposium on Flexible Automation - A Pacific Rim Conference	Kyoto, Japan	Professor Toshihiro Tsumura c/o Institute of Systems, Control at Engineers 14 Yoshida-Kawahara-cho Sakyo-ku, Kyoto 606
July 11-13	The 5th International Conference on Manufacturing Engineering	Wollongong, Australia	The Conference Manager The Institution of Engineers, Australia 11 National Circuit Barton, ACT 2600

1990			
Date	**Title/Attendance**	**Site**	**Contact for Information**
July 11-13	The 3rd Optoelectronics Conference (OEC '90) 8-F20-J350	Tokyo, Japan	Katsuyoshi Ito OEC '90 Publicity & Registration Subcommittee Chair c/o Business Center for Academic Societies Japan Conference Department, Crocevia Crocevia Hongo 2F 3-23-1 Hongo Bunkyo-ku, Tokyo 113
July 12-14	Meeting on Advanced Research on Computers in Education	Tokyo, Japan	M. Hosaka Kikaishinko-kai 3-5-8 Shiba Koen Minato-ku, Tokyo 105
July 12-14	The 2nd International Symposium on Magnetic Bearings	Tokyo, Japan	Professor Toshiro Higuchi Institute of Industrial Science Tokyo University 7-22-1 Roppongi Minato-ku, Tokyo 106
July 15-21	The 10th International Congress of Nephrology 10-F1,000-J4,000	Tokyo, Japan	Japanese Society of Nephrology c/o 2nd Department of Internal Medicine School of Medicine, Nippon University 30-1 Oyaguchi-kamicho Itabashi-ku, Tokyo 173
July 16-20	Pacific Congress on Marine Science and Technology (PACON 90)	Tokyo, Japan	PACON 90 College of Science and Technology Nihon University 1-8-14 Surugadai, Kanda Chiyoda-ku, Tokyo 101
July 16-21	ISEC '90 International Solvent Extraction Conference	Kyoto, Japan	Conference Secretariat ISEC '90 Department of Chemistry Science University of Tokyo Kagurazaka, Shinjuku-ku, Tokyo 162
July 18-20	Advanced Research on Computers in Education	Tokyo, Japan	Professor Setsuko Otsuki Faculty of Computer Science and Systems Engineering Kyushu Institute of Technology 1-1 Sensui-cho, Tobata-ku Kitakyushu-shi, Fukuoka 804
July 18-21	The 3rd International Symposium on Human Factors in Organizational Design and Management	Kyoto, Japan	Dr. Junzo Watada Symposium Secretariat 3rd International Symposium on Human Factors in Organizational Design and Management c/o Faculty of Business Administration Ryukoku University Fukakusa, Fushimi, Kyoto 612
July 19-21	The 22nd International Congress of Applied Psychology (22nd ICAP) (Workshop)	Kyoto, Japan	Professor Yasuhisa Nagayama General Secretariat 22ICAP P.O. Box 38 Suita-Senri, Osaka 565
July 20-24	International Conference on Fuzzy Logic and Neural Networks (IIZUKA'90)	Fukuoka, Japan	Professor Takeshi Yamakawa Department of Computer Science and Control Engineering Kyushu Institute of Technology 680-4 Kawazu, Ohaza Iizuka-shi, Fukuoka 820
July 22-25	The 5th Asia-Pacific Confederation of Chemical Engineering (APCChE 1990)	Kuala Lumpur, Malaysia	Conference Secretary APCChE Conference 1990 c/o The Institution of Engineers, Malaysia P.O. Box 223 (Jln Sultan) 46720 Petaling Jaya Malaysia

1990			
Date	**Title/Attendance**	**Site**	**Contact for Information**
July 22-27	The 22nd International Congress of Applied Psychology (22 ICAP)	Kyoto, Japan	Professor Yasuhisa Nagayama General Secretariat, 22ICAP P.O. Box 38 Suita-Senri, Osaka 565
July 24-26	The 29th SICE Annual Conference (SICE'90)	Tokyo, Japan	Dr. Suguru Arimoto c/o The Society of Instrument and Control Engineers (SICE) 1-35-28-303 Hongo Bunkyo-ku, Tokyo 113
July 29-August 3	IAWPRD BIENNIAL '90 (International Association on Water Pollution Research and Control)	Kyoto, Japan	Jun-ichiro Matsumoto, Chairman, Japanese Organizing Committee c/o Japan Society on Water Pollution Research Yotsuya New Mansion 307 12 Honshio-cho Shinjuku-ku, Tokyo 160
July 30-August 2	The 15th International Conference on International Association on Water Pollution Research and Control	Kyoto, Japan	Japan Society on Water Pollution Research and Control Yotsuya New Mansion 12 Honshiocho Shinjuku-ku, Tokyo 173
August 2-8	The 25th International Conference on High Energy Physics 1990	Singapore	Professor K.K. Phua South East Asia Theoretical Physics Association c/o Dept. of Physics National University of Singapore Kent Ridge, Singapore 0511
August 3-6	International Conference on the Environmental Management of Enclosed Coastal Seas '90 (EMECS '90)	Kobe, Japan	Secretariat Exec. Comm. of the International Conference on the Environmental Management of Enclosed Coastal Seas 5-10-1 Shimoyamate-dori Chuo-ku, Kobe 650
August 6-9	International Conference on Advanced Materials Mechanical Properties '90 (ICAMP'90)	Utsunomiya, Japan	Secretariat ICAMP'90 P.O. Box 1234, Shibuya Shibuya-ku, Tokyo 150
August 6-10	The 5th International Meeting of the International Humic Substances Society (IHSS5)	Nagoya, Japan	Registration Secretariat: 5th IHSS c/o Japan Convention Services, Inc. Nagoya Branch Nagoya International Building, 19th Floor 1-47-1 Nagono Nakamura-ku, Nagoya 450
August 7-11	International Symposium on Analytical Chemistry	Changchun, People's Republic of China	Professor Qinhan Jin Dept. of Chemistry Changchun, China
August 7-12	The 6th International Symposium on Biology of Turbellaria	Hirosaki, Japan	Professor Wataru Teshirogi Department of Biology Faculty of Science Hirosaki University 3 Bunkyo-cho Hirosaki, Aomori 036
August 12-17	The 15th International Carbohydrate Symposium	Yokohama, Japan	Dr. Ishido, General Secretary Faculty of Science Tokyo Institute of Technology Ookayama, Meguro-ku, Tokyo 152

1990			
Date	**Title/Attendance**	**Site**	**Contact for Information**
August 13-17	The 4th Asia Pacific Physics Conference	Seoul, Korea	Program Committee, AAPC Department of Physics Yonsei University Seoul 120-749, Republic of Korea
August 16-18	SIGNAL International Symposium on Algorithms	Tokyo, Japan	Professor Tetsuo Asano Department of Applied Electronics Osaka Electro-Communications University 18-8 Hatsu-cho Neyagawa-shi, Osaka 572
August 18-20	General Assembly, International Mathematical Union 52-F124-J6	Kobe, Japan	ICM 90 Secretariat c/o Research Institute for Mathematical Sciences Kyoto University Oiwake-cho, Kitashirakawa Sakyo-ku, Kyoto 606
August 20-21	The 7th VLSI Process/Device Modeling Workshop	Kawasaki, Japan	Mr. Hiroshi Iwai ULSI Research Center, Toshiba Corp. 1 Komukai-Toshiba-cho Saiwai-ku, Kawasaki 210
August 20-24	1990 International Symposium on Symbolic and Algebraic Computation 15-F60-J140	Tokyo, Japan	ISSAC '90 Conference Office c/o Scientist, Inc. Yamazaki Building 3-2 Kanda-Surugadai Chiyoda-ku, Tokyo 101
August 21-29	International Congress of Mathematicians 1990 84-F1,500-J1,500	Kyoto, Japan	ICM 90 Secretariat c/o International Relations Office Research Institute for Mathematical Sciences Kyoto University Kitashirakawa Oiwake-cho Sakyo-ku, Kyoto 606
August 22-24	1990 International Conference on Solid State Devices and Materials N.A.-F100-J900	Sendai, Japan	c/o Business Center for Academic Societies Japan Crocevia Building 2F 3-23-1 Hongo Bunkyo-ku, Tokyo 113
August 23-30	V International Congress of Ecology 62-F900-J1,000	Yokohama, Japan	Secretary General's Office for INTECOL 1990 c/o Institute of Environmental Science and Technology Yokohama National University 156 Tokiwadai Hodogaya-ku, Yokohama 240
August 26-31	AUSTCERAM 90	Perth, Australia	The Conference Secretariat, AUSTCERAM 90 P.O. Box 515 South Perth, WA 6151, Australia
August 28-31	International Conference & Exhibition on Computer Applications to Materials Science and Engineering (CAMSE 90)	Tokyo, Japan	Professor M. Doyama CAMSE '90 c/o The Nikkan Kogyo Shimbun, Ltd. Business Bureau 1-8-10 Kudan Kita Chiyoda-ku, Tokyo 102
August 29-September 4	The 11th International Symposium on Biotelemetry N.A.-F120-J250	Yokohama, Japan	Professor A. Uchiyama Department of Electronics & Communication School of Science and Engineering Waseda University 3-4-1 Okubo Shinjuku-ku, Tokyo 169

1990			
Date	**Title/Attendance**	**Site**	**Contact for Information**
August 30- September 4	International Conference on Potential Theory 24-F50-J200	Nagoya, Japan	Secretariat International Conference on Potential Theory c/o Department of Mathematics College of General Education Nagoya University Furo-cho, Chikusa-ku, Nagoya 464-01
August 30- September 4	International Symposium on Computational Mathematics 10-F30-J50	Matsuyama, Japan	Professor T. Yamamoto Department of Mathematics Ehime University 2-5 Bunkyo-machi, Matsuyama 790
September 3-5	International Symposium on Diagnostics and Modeling of Combustion in Internal Combustion Engines (COMODIA 90)	Kyoto, Japan	Professor Makoto Ikegami Dept. of Mechanical Engineering Kyoto University Sakyo-ku, Kyoto 606
September 4-7	The 2nd International Symposium on Chemical Synthesis of Antibiotics and Related Microbial Products 15-F70-J180	Oiso, Japan	Faculty of Pharmaceutical Sciences University of Tokyo 7-3-1 Hongo Bunkyo-ku, Tokyo 113
September 10-14	The 17th Congress of the Collegium International Neuro-Psychopharmacologicum	Kyoto, Japan	The 17th CINP Congress c/o Simul International Inc. Kowa Building No. 1 1-8-10 Akasaka Minato-ku, Tokyo
September 11-14	The 12th International Symposium on Capillary Chromatography	Kobe, Japan	Assistant Professor Kiyokatsu Jinno School of Material Engineering Toyohashi University of Technology 1-1 Hibarigaoka, Aza Tenpaku-cho, Toyohashi-shi 440
September 16-20	The 4th International Conference on Copepoda	Karuizawa, Japan	Professor Shin-ichi Uye Hiroshima University, Shitami Shaijo-cho, Higashi-Hiroshima 724
September 16-22	The 15th IUMS Congress: Bacteriology & Mycology - Osaka, Japan - 1990 71-F2,000-J3,500	Osaka, Japan	Secretary General c/o Department of Microbiology Faculty of Medicine Kyoto University Yoshida, Konoe-cho Sakyo-ku, Kyoto 606
September 18-21	The 3rd Asia-Pacific Microwave Conference (APMC '90) 30-F150-J350	Tokyo, Japan	APMC '90 Secretariat c/o Business Center for Academic Societies Japan 3-23-1 Hongo Bunkyo-ku, Tokyo 113
September 19-22	The 2nd World Congress on Particle Technology N.A.-F100-J400	Kyoto, Japan	Secretariat: 2nd World Congress on Particle Technology c/o Society of Powder Technology, Japan Shibunkaku-kaikan 2-7 Tanakasekiden-cho Sakyo-ku, Kyoto 606
September 20-23	The 3rd Shallow Tethys International Symposium	Sendai, Japan	Secretariat of Shallow Tethys 3 c/o Institute of Geology and Paleontology Faculty of Science Tohoku University Aobayama, Sendai 980

1990			
Date	**Title/Attendance**	**Site**	**Contact for Information**
September 23-27	The 57th World Foundry Congress (WFC) 31-F400-J800	Osaka, Japan	Secretariat Japan Foundrymen's Society Toyokawa Building 8-12-13 Ginza Chuo-ku, Tokyo 104
September 24-27	The 6th International Congress on Polymers in Concrete	Shanghai, People's Republic of China	ICPIC-90 Secretariat c/o Associate Professor Tan Muhua Institute of Materials Science and Engineering Tongji University Shanghai
September 24-27	The 3rd International Aerosol Conference 29-F200-J300	Kyoto, Japan	Professor Kanji Takahashi c/o Institute of Atomic Energy Kyoto University Uji, Kyoto 611
September 24-28	The 3rd International Aerosol Conference	Kyoto, Japan	Professor Kanji Takahashi, General Secretary Institute of Atomic Energy Kyoto University Uji, Kyoto 611
September 24-28	The 12th International Conference: Boundary Element Method Conference (BEM 12)	Sapporo, Japan	Mr. Hiroshi Mizoguchi JASCHOME, KKE Inc. Dai-ichi Seimei Building 24F 2-7-1 Nishi-Shinjuku Shinjuku-ku, Tokyo 160
September 28-October 2	The 4th International Symposium on Benthic Foraminifera: BENTHOS '90	Sendai, Japan	Organizing Committee for 4th Int'l. Symp. on Benthic Foraminifera c/o Institute of Geology and Paleontology Faculty of Science Tohoku University Aobayama, Sendai 980
October 1-5	International Conference on Information Technology Commemorating the 30th Anniversary of the Information Processing Society of Japan (IPSJ) - InfoJapan '90 20-F200-J1,000	Tokyo, Japan	*InfoJapan* '90 Secretariat: IPSJ Hoshina Building 3F 2-4-2 Azabudai Minato-ku, Tokyo 106
October 1-5	The 3rd International New Materials Conference (New Materials 90 Japan) 12-F100-J300	Osaka, Japan	Secretariat: New Materials 90 Japan c/o Inter Group Corp. Shohaku Building 6-23 Chayamachi Kita-ku, Osaka 530
October 2-5	The 4th International Conference on Shotpeening	Tokyo, Japan	Secretariat: ICSP The Japan Society of Precision Engineering Ceramics Building 2-22-17 Hyakunin-cho Shinjuku-ku, Tokyo 169
October 8-10	The 1st International Workshop on Algorithmic Learning Theory (ALT'90)	Tokyo, Japan	Professor Setsuo Arikawa Program Chairman of ALT'90 Research Institute of Fundamental Information Science Kyushu University 33 Fukuoka 812
October 8-11	"Benibana" International Symposium on How to Improve the Toughness of Polymers and Composites	Yamagata, Japan	Professor Ikuo Narisawa Polymer Materials Engineering Yamagata University 4-3-16 Jonan Yonezawa-shi, Yamagata 992

1990			
Date	**Title/Attendance**	**Site**	**Contact for Information**
October 8-12	The 5th Australasian Remote Sensing Conference	Perth, Australia	Gold West Conventions P.O. Box 411 West Perth, WA 6005
October 9-12	Fracture and Fatigue of High-Performance and Multi-Phase Polymeric Materials 8-F25-J60	Undecided, Japan	Faculty of Engineering Yamagata University 4-3-16 Jonan Yonezawa, Yamagata 992
October 14-19	International Conference for New Smelting Reduction and Near Net Shape Casting Technologies for Steel	Pohang, Korea	Conference Department Institute of Metals 1 Carlton House Terrace London, SW1Y 5 5DB, U.K.
October 15-18	The 1st Asian-Pacific International Symposium on Combustion and Energy Utilization	Beijing, People's Republic of China	Professor Huang, Zhao Xiang and Song Jialin Institute of Engineering Thermophysics Chinese Academy of Sciences P.O. Box 2706, Beijing
October 15-19	The 4th International Symposium on Marine Engineering (ISME KOBE '90)	Kobe, Japan	ISME Organizing Committee c/o Kobe Shosen Daigaku 5-1-1 Fukae-Minami Higashinada-ku, Kobe 658
October 15-19	The 8th International Symposium on Vit. B6 and Carbonyl Catalysis	Osaka, Japan	Institute of Scientific and Industrial Research 8-1 Mihogaoka Ibaraki, Osaka 567
October 21-26	The 6th International Iron and Steel Congress 50-F300-J500	Nagoya, Japan	International Conference Department Iron and Steel Institute of Japan 3F, Keidanren Kaikan 1-9-4 Otemachi Chiyoda-ku, Tokyo 100
October 22-25	The 11th International Coal Preparation Congress N.A.-F250-J150	Tokyo, Japan	Secretariat 11th International Coal Preparation Congress c/o Simul International, Inc. Kowa Building, No. 9 1-8-10 Akasaka Minato-ku, Tokyo 107
October 22-25	The 10th International Acoustic Emission Symposium 1990 (IAES-10)	Sendai, Japan	Professor Hiroaki Niitsuma Faculty of Engineering Tohoku University Aramaki Aza Aoba, Sendai 980
October 22-26	International Conference on Signal Processing	Beijing, People's Republic of China	Professor Zong Sha Nongzhan Guan Nan Lu 12, Room 2307 Beijing 100026
October 22-26	International Conference on Information Technology in Connection with 30th Anniversary Celebration of Information Processing Society of Japan N.A.-F200-J1,000	Osaka, Japan	Secretariat: International Conference on Information Technology c/o Simul International, Inc. Kowa Building, No. 9 1-8-10 Akasaka Minato-ku, Tokyo 107
October 25-31	The 1st Japanese Knowledge for Knowledge-Based Systems Workshop (JKAW)	Kyoto, Japan	Assoc. Professor Riichiro Mizoguchi The Institute of Scientific and Industrial Research 8-1 Mihogaoka Ibaraki, Osaka 567

1990			
Date	**Title/Attendance**	**Site**	**Contact for Information**
October 28-November 2	The 2nd International Conference: HSLA Steels	Beijing, People's Republic of China	Chinese Society of Metals 46 Dongsixi Dajie, Beijing 100711
October 29-November 1	Japan International Tribology Conference Nagoya - '90 N.A.-F100-J500	Osaka, Japan	Secretariat: Japan ITC Nagoya - '90 c/o Toyota Technological Institute 2-chome, Hisakata Tempaku-ku, Nagoya 468
November 4-8	International Symposium on Carbon, 1990: "New Processing and New Applications" 15-F50-J200	Tsukuba, Japan	The Carbon Society of Japan Saito Building 2F 2-16-13 Yujima Bunkyo-ku, Tokyo 113
November 5-8	The 9th International Symposium on Zirconium in the Nuclear Industry	Kobe, Japan	American Society for Testing and Materials (ASTM) Conference Department 1916 Race Street Philadelphia, PA 19103
November 7-9	IUPAC International Symposium on Specialty Polymers	Singapore	Professor S.H. Goh Department of Chemistry National University of Singapore 10 Kent Ridge Crescent Singapore 0511
November 14-16	Rare Metals '90 15-F100-J200	Kitakyushu, Japan	Mining and Materials Processing Institute of Japan (MMIJ) Nogizaka Building 9-6-41 Akasaka Minato-ku, Tokyo 107
November 19-22	Asia Pacific Interfinish 90 Congress	Hong Kong	Asia Pacific Interfinish 90 c/o Australasian Institute of Metal Finishing 191 Royal Parade Parkville, VIC 3052, Australia
November 26-29	The 3rd International Polymer Conference (3rd IPC) 5-F100-J200	Nagoya, Japan	IPC Secretariat c/o Society of Polymer Science, Japan 5-12-8 Ginza Chuo-ku, Tokyo 104
November 26-30	The 5th International Photovoltaic Science and Engineering Conference (International PVSEC-5)	Kyoto, Japan	Professor Junji Saraie Secretariat of International PVSEC-5 c/o Japan Convention Services, Inc. Nippon Press Center Building 2-2-1 Uchisaiwai-cho Chiyoda-ku, Tokyo 100
1990 (tentative)	Chemeca 1990 Applied Thermodynamics	New Zealand	Conference Manager The Institution of Engineers, Australia 11 National Circuit Barton, ACT 2600

1991			
Date	**Title/Attendance**	**Site**	**Contact for Information**
February 7-12	The 10th International Conference on Offshore Mechanics and Arctic Engineering	Seoul, Korea	Korea Cmt for Ocean Resources and Engineering Dong-A University 840 Sahagu Pusan, Korea
February 10-15	POLYMER '91: International Symposium on Polymer Materials	Melbourne, Australia	Dr. G.B. Guise P.O. Box 224 Belmont, VIC 3216, Australia
May 7-13	Beijing Essen Welding '91	Beijing, People's Republic of China	Messe Essen Nobert Street D-4300 Essen Federal Republic of Germany
June 10-12	The 3rd International Conference on Hot Isostatic Pressing	Osaka, Japan	Professor Yoshinari Miyamoto Processing Research Center for High Performance Materials Institute of Scientific and Industrial Research Osaka University 8-1 Mihogaoka Ibaraki-shi, Osaka 567
June 10-13	International Conference on Stainless Steels 20-F50-J100	Tokyo, Japan	Secretariat: STAINLESS STEELS '91 The Iron and Steel Institute of Japan Keidanren Kaikan 1-9-4 Otemachi Chiyoda-ku, Tokyo 100
June 10-14	The 4th International Conference on Nucleus-Nucleus Collisions 20-F200-J200	Kanazawa, Japan	Institute of Physical and Chemical Research (RIKEN) 2-1 Hirosawa Wako, Saitama 351-01
June 12-15	The 18th International Materials Handling, Storage and Distribution Exhibition and Conference	Tokyo, Japan	Show Management, Yoshihisa Shiraishi Convention Department, Japan Management Association 3-1-122 Shiba Koen Minato-ku, Tokyo 105
June 17-21	The 10th International Symposium on the Mathematical Theory of Networks and Systems (MTNS-91)	Kobe, Japan	Professor Hidenori Kimura Department of Mechanical Engineering for Computer-Controlled Machinery Faculty of Engineering Osaka University 2-1 Yamadaoka Suita-shi, Osaka 565
June (tentative)	JIMIS-6: Intermetallic Compound - Properties and Applications	Tokyo, Japan	Professor Osamu Waizumi Institute for Materials Research 2-1-1 Katahira Sendai 980
July 7-12	The 16th International Conference on Medical and Biological Engineering (ICMBE) 45-F600-J1,400	Kyoto, Japan	Japan Society of Medical Electronics and Biological Engineering 2-4-16 Yayoi Bunkyo-ku, Tokyo 113
July 7-12	The 9th International Congress on Medical Physics (ICMP) 54-F1,000-J1,500	Kyoto, Japan	c/o Division of Physics National Institute of Radiological Science 4-9-1 Anagawa Chiba 260
July 24-26	The 3rd International Conference on Residual Stresses (ICRS-3) 30-F150-J200	Tokushima, Japan	Society of Materials Sciences, Japan 1-101 Yoshida Izumidono-cho Sakyo-ku, Kyoto 606

1991			
Date	Title/Attendance	Site	Contact for Information
July 24-30	The 17th International Conference on the Physics of Electronic and Atomic Collisions	Brisbane, Australia	Dr. W.R. Newell Department of Physics University College of London Gower Street London WC1E 6BT UK
July 29-August 2	The 6th International Conference on Mechanical Behavior of Materials (ICM-6) 30-F300-J300	Kyoto, Japan	Society of Materials Sciences, Japan 1-101 Yoshida Izumidono-cho Sakyo-ku, Kyoto 606
August 25-31	International Congress on Analytical Science-1991 (ICAS '91) 25-F500-J1,000	Chiba, Japan	The Japan Society for Analytical Chemistry Rm 304 Gotanda Sun Heights 1-26-2 Nishi Gotanda Shinagawa-ku, Tokyo 141
August (tentative)	The 16th International Conference on Medical and Biological Engineering (ICMBE)	Kyoto, Japan (tentative)	Japan Society of Medical Electronics and Biological Engineering 2-4-16 Yoyogi Bunkyo-ku, Tokyo 113
September 29-October 4	The 5th Asian Pacific Congress of Clinical Biochemistry (5th APCCB) 20-F300-J600	Kobe, Japan	Secretariat: 5th APCCB c/o Central Laboratory for Clinical Investigation Osaka University Hospital 1-1-50 Fukushima Fukushima-ku, Osaka 553
October 28-31	International Conference on Fast Reactors and Fuels Cycles 8-F150-J350	Kyoto, Japan	Power Reactor & Nuclear Fuel Development Corp. 1-9-13 Akasaka Minato-ku, Tokyo 107
November (tentative)	The 1st Japan-China Joint Seminar of Filtration and Separation	Undecided, People's Republic of China	
Undecided 1991	The 9th International Conference on Hot Carriers in Semiconductors 10-F50-J100	Nara, Japan	Department of Electronics Osaka University 2-1 Yamada-Oka Suita, Osaka 565

1992			
Date	Title/Attendance	Site	Contact for Information
February (tentative)	The 19th Australian Polymer Symposium	Perth, Australia	RACI Polymers Division P.O. Box 224 Belmont, VIC 3216
May 17-22 (tentative)	NETWORKS '92: The 5th International Network Planning Symposium 20-F200-J200	Kobe, Japan	NTT Telecommunication Networks Laboratories 3-9-11 Midori-cho Musashino-shi, Tokyo 180
August 30-September 4	The 9th International Congress on Photosynthesis	Nagoya, Japan	Professor Norio Murata Okazaki National Research Institute National Research for Basic Biology 38 Saigou-Naka, Miyoudaigi-cho-aza Okazaki, Aichi

1992

Date	Title/Attendance	Site	Contact for Information
October 26-30	The 14th International Switching Symposium (ISS '92) 60-F1,200-J800	Yokohama, Japan	NTT Communication Switching Laboratories 3-9-11 Midori-cho Musashino-shi, Tokyo 180
November 9-12	The 8th International Congress on Heat Treatment of Materials N.A.-FJ500	Osaka, Japan (tentative)	Secretariat of 8th International Congress on Heat Treatment of Materials c/o Research Institute for Applied Science 49 Tanaka Ohi-cho Sakyo-ku, Kyoto 606

1993

Date	Title/Attendance	Site	Contact for Information
February 16-20	The 15th International Congress of Clinical Chemistry	Melbourne, Australia	Multinational Meeting Information Services BV J W Brouwersplein 27 P.O. Box 5090 1007 AB Amsterdam, The Netherlands
May 23-28	The 18th International Mineral Processing Congress	Sydney, Australia	AUSIMM, Conference Department P.O. Box 122 Parkville, VIC 3052
August 8-13	The 8th International Congress of Virology	Osaka, Japan	Professor Stuart W. Glover, Secretary General Int'l Union of Microbiological Societies Dept of Genetics, Catherine Cookson Bldg Framlington Place Nerocastle upon Tyne NE2 4HU, UK
1993 (tentative)	International Federation of Automatic Control Congress	Sydney, Australia	Conference Manager The Institution of Engineers, Australia 11 National Circuit Barton, ACT 2600

1994

Date	Title/Attendance	Site	Contact for Information
Tentative	XXX International Conference on Coordination Chemistry	Kyoto, Japan	Professor Hitoshi Ohtaki Coordination Chemistry Laboratories Institute for Molecular Science Myodaiji-cho, Okazaki 444
Tentative	The 10th International Conference on the Strength of Metals and Alloys (ICSMA-10)	Undecided, Japan	Professor Hiroshi Oikawa Faculty of Engineering Tohoku University Aoba, Aramaki Aza Sendai 980

1995

Date	Title/Attendance	Site	Contact for Information
Tentative	The 13th International Vacuum Congress (IVC-13) The 7th International Conference on Solid Surfaces (ICSS-7)	Undecided, Japan	Vacuum Society of Japan 302 Kikai Shinko Kaikan Annex 3-5-22 Shiba-koen Minato-ku, Tokyo 105

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NOTICE

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